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Technical Report 70-2

Methods of Training for the Engagement of Aircraft With Small Arms

by

E.W. Frederickson, Robert D. Baldwin, and Robert J. Foskett

HumRRO Division No. 5

February 1970

Prepared for:

Office, Chief of Research and Development Department of the Army

Contract DAHC 19-70-C-0012

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HumRRO

HUMAN RESOURCES RESEARCH ORGANIZATION

57

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HumRRO Division No. 5
Fort Bliss, Texas
HUMAN RESOURCES RESEARCH ORGANIZATION

Technical Report 70-2
Work Unit SKYFIRE

The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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FOREWORD

Since 1965, HumRRO has been conducting studies concerning man's capabilities to perform the skills required for operation of forward area air defense weapons. This research has included studies of human capability to visually detect and recognize aircraft and to estimate open- and cease-fire distances. This work was initiated under Exploratory Study 44, Forward Area Air Defense Weapons, and has been continued since FY 1967 under Work Unit SKYFIRE. It has been performed by HumRRO Division No. 5, Fort Bliss, Texas, with Dr. Robert D. Baldwin as Director.

The research described in this report concerns Technical Advisory Services (TAS) related to Work Unit SKYFIRE and provided to the U.S. Army Infantry School (USAIS), concerning the use of small arms in an air defense role. The studies were described in three reports submitted to USAIS:

(1) A description of a full-scale approach to training not involving any live firing, submitted in December 1965.

(2) A description of a proposed experimental method involving reduced-scale facilities and subcaliber firing, submitted in October 1966.

(3) A description of the results of a test of the reduced-scale training program, submitted in January 1967.

This Technical Report consolidates information presented in these previous Consulting Reports, which were distributed only to the USAIS at the time of their individual publication. Other Technical Reports published or in preparation under Work Unit SKYFIRE and ES-44 are:

The Performance of Ground Observers in Detecting, Recognizing, and Estimating Range to Low-Altitude Aircraft, Technical Report 66-19, December 1966.

Aircraft Detection, Range Estimation, and Auditory Tracking Tests in a Desert Environment, Technical Report 67-3, March 1967.

Studies on Training Ground Observers to Estimate Range to Aerial Targets, Technical Report 68-5, May 1968.

Determination of Ground-to-Aircraft Distances by Visual Techniques, HumRRO Technical Report 69-22, December 1969.

"Aircraft Recognition Performance of Crew Chiefs With and Without Forward Observers," Technical Report in preparation.

"Auditory and Visual Tracking of a Moving Target," Technical Report in preparation.

Military support for the study was provided by the U.S. Army Air Defense Human Research Unit. The military chiefs of the Unit successively were LTC Leo M. Blanchett and MAJ Alexander D. Bell. The Project Officers at the USAIS during the small arms studies were CPT W.T. Reeves, 1LT M.L. Perkins, 1LT M.O. O'Neill, and CPT C.E. Newbern.

The research was performed and most of the report preparation completed while HumRRO was part of The George Washington University.

Mr. R.J. Foskett, Research Scientist, HumRRO Division No. 5, developed the mathematical method for determining parameters for a reduced-scale training facility; Mr. Edward Kingsley, Mathematician for Project IMPACT, HumRRO Division No. 1, generalized the method developed by Mr. Foskett and stated it in more abstract terms.

HumRRO research for the Department of the Army is conducted under Contract DAHC 19-70-C-0012. Training, Motivation, Leadership Research is conducted under Army Project 2Q062107A712.

Meredith P. Crawford
President
Human Resources Research Organization

SUMMARY AND CONCLUSIONS

MILITARY PROBLEM

Low-altitude air assault tactics are emphasized by the major powers. This emphasis has created a need for U.S. forward area ground forces to have a capability for air defense using only organic infantry weapons. Current doctrine gives primary attention to passive air defense measures, such as use of cover and concealment for infantry forces. A unit attacked by aircraft would be authorized to return fire but, although active air defense is authorized at present, there has been no provision during either individual or unit training programs for instruction in the engagement of aircraft with small arms.

Because of the large number of personnel needing this type of training, the Department of the Army wanted an instructional program that did not require live firing against drone or towed targets, since such an approach to training would involve considerable cost.

RESEARCH PROBLEM

Other research conducted by HumRRO under Work Units STAR and SKYFIRE (and prior Exploratory Studies) had yielded data indicating that deployed forces had the capability of detecting, recognizing, and accurately estimating the range of low-altitude aircraft. The major problems that remained for the research involved the development of methods of training infantrymen to engage aircraft without actually firing service weapons during the training.

METHOD AND RESULTS

Two approaches were used in developing training for engaging aircraft with small arms. The first approach involved practice in leading and tracking with a special training device in a full-scale environment. The second approach employed a miniaturized training facility in which men practiced leading, tracking, and firing air rifles (BB guns) against 1/10-scale silhouette targets mounted above a 1/4-ton vehicle. Both training methods included practice in estimating the open- and cease-fire ranges (350 meters), using either the front sight guard of the M14 rifle or the finger occlusion technique as stadimetric ranging aids.

Full-Scale Training Program

The full-scale approach did not involve any live firing during training. This training program was demonstrated at Fort Benning, Georgia, in January 1966. It employed a "Lead Tracking Training Device" designed by HumRRO, which was used by the trainees to track and lead a U-6A U.S. Army aircraft flying at 100 knots at altitudes below 300 feet and at crossing ranges varying from 100 to 200 meters. Sixteen men were trained in range estimation and in leading and tracking in an eight-hour program.

The effectiveness of the non-firing training program was evaluated on the next day by requiring the men to fire the service rifle (M14) against an MK-23 sleeve target towed at 100 knots by a U.S. Navy US-2C aircraft. The men fired in two groups of eight men each. The first group fired a total of 470 rounds of 7.62mm ball ammunition and achieved three hits on the sleeve. The second group fired 490 rounds and achieved seven hits.

The hit frequencies in the test were mathematically adjusted to allow for the smaller size of the towed sleeve in comparison with an O-1A aircraft. On the basis of this adjustment, it was computed that approximately 3.8% of the rounds fired would have hit the full-sized target. This hit proportion was similar to that achieved in previous extensive live firing tests.

Miniaturized Training Method

In January 1967, a miniaturized training program which had been developed jointly by HumRRO and the Technique of Fire Team of the U.S. Army Infantry School was demonstrated at Fort Benning. The program was designed to train up to 200 men during one six-hour training period.

Twenty riflemen participated in the demonstration and test of the training method. The training facilities consisted of training stations at which instruction was offered in the following areas:

(1) A conference concerning the fundamental skills involved in aircraft engagement.

(2) Introduction to aircraft recognition, and familiarization with a coach-pupil method of using flash cards for learning this skill.

(3) Range estimation using stadimetric aids.

(4) Introduction to lead estimation using a static target.

(5) Practice in leading, tracking, and firing air rifles at miniaturized moving silhouettes of aircraft.

(6) Familiarization and record firing using the air rifle against 1/10-scale silhouette targets transported by a 1/4-ton vehicle.

On the next day, the 20 riflemen who had received this instruction were administered a live firing test, involving use of the service rifle against MK-23 target sleeves towed by a U.S. Navy US-2C aircraft. The target was towed at approximately 155 knots, at altitudes of 100 to 300 feet, and at minimum crossing distances of 75 to 200 meters.

A second group of 20 riflemen, who were members of the Technique of Fire Team, also fired against the towed sleeve. These men had received no training in engaging aerial targets except instructions to lead the aircraft.

The riflemen in both groups fired in orders of ten men each. They were instructed to fire, if possible, the complete magazine of 20 rounds during each flight of the sleeve; the desired firing rate was approximately one round per second. Each order of ten riflemen fired for a total of five successive flights.

The trained group fired a total of 1964 rounds and achieved 13 hits. The untrained group fired 2000 rounds and obtained four hits. The results were adjusted mathematically for the difference between the sizes of the sleeve and a tactical aircraft. It was estimated that the trained group would have obtained 2.3% hits, whereas the untrained group would have obtained 0.7% hits on a tactical target.

COMPARISON OF THE TWO PROGRAMS

The full-scale method of training tested in 1966 employed no live firing practice against moving targets, but used training devices for practicing leading and tracking full-scale aircraft. The devices were designed to employ a coach-pupil method, which

permitted provision of individualized feedback to each trainee (pupil) during each pass of the target aircraft.

The miniaturized training program tested in 1967 did not make provision for individual feedback to each trainee concerning his leading and tracking accuracy. Since the trainees fired the air rifles in groups, it was not possible to provide error information to each trainee.

When the service weapon firing results were compared for the two programs, the scaled-up hit percentage of 3.8% after the full-scale non-firing program was found to be statistically greater than the 2.3% hit rate obtained by the miniaturized training group.

CONCLUSIONS

Both the full-scale and the miniaturized training programs were considered to be effective in developing, within a short period of time, some skill in engaging aircraft with small arms.

Each program contained features that afforded economical means of accomplishing the training requirement.

On the basis of an analysis of the two programs, and of the various suggestions for improving these programs (see Chapter 4), it appeared that an optimum training technique should result if the training devices employed in the full-scale method were incorporated in a program that used miniaturized targets, with instruction on the devices preceding familiarization firing with the subcaliber weapon.

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Methods of Training for the Engagement of Aircraft With Small Arms

Chapter 1

PROBLEM AND RESEARCH REQUIREMENTS

MILITARY PROBLEM

The increased emphasis on low-altitude air assault tactics by both U.S. and foreign forces has created a corollary need to provide increased air defense capabilities for deployed U.S. ground forces.

The weapons that are available for low-altitude air defense are small arms organic to the infantry company, the larger-caliber automatic weapons, the man-transportable Redeye missile system, and the Chaparral air defense weapon. All of these weapons have varying effectiveness against the variety of aircraft that will penetrate the forward area. Events in Vietnam, however, have convincingly demonstrated that even the basic infantry weapons can be effectively employed against jets as well as slower aircraft.

In contrast to the radar-controlled air defense systems that are deployed to the rear of the field army area, the weapons being considered by the Army for forward area air defense operations are man-ascendant rather than machine-ascendant systems. Man-ascendant weapons all depend upon basic human skills to (a) detect and recognize the aircraft, (b) estimate its distance, altitude, and speed, (c) track the target, (d) determine when the target is within the air defense weapon's capability envelope, and (e) engage the target. In a machine-ascendant system, all or most of these functions are aided or accomplished by electronic circuits. In a man-ascendant system, they must be accomplished by the system operator, be he a rifleman, a crewman, or a gunner. Because these weapons are man-ascendant, they are considered at the present time to be fair weather systems only—that is, they have little or no capability under conditions of poor visibility.

For U.S. ground forces, training in the basic skills required for using direct fire weapons against low-altitude aircraft ceased at the end of World War II, except for training given units issued the M55 Quad .50-caliber system and the M42, 40-mm system. With the advent of the machine-ascendant radar-controlled weapons and the increasing speeds of jet aircraft, it was believed that small- to medium-caliber weapons were essentially useless in an air defense role.

However, the extensive use of helicopters and the reduced speeds of jets when flying at low altitudes have re-created types of low-altitude air threats once thought to be obsolete. The aerial threat in the forward area will consist of rotary wing transports and armed close support vehicles, operating at speeds between zero and 150 knots; fixed-wing reconnaissance aircraft, both manned and drone, varying in speed from 75 to 300 knots; and jet attack aircraft, which operate at approximately 400 to 500 knots when attacking ground targets.

The effectiveness of a forward area weapon is a joint function of the single-shot ballistic effectiveness of the projectile, the number of projectiles fired, the technique of engagement, the skills of the user, the nature of the target, and visibility conditions. At the present time, sufficient test data are not available to validly describe the total effectiveness of each type of forward area air defense weapon when placed in the hands of the typical user. Although gun camera and live firing tests have recently been

conducted using reduced-scale targets (1), there is an absence of test data involving live firing at full-size targets.

BACKGROUND

The general objectives of the SKYFIRE research are (a) to determine man's capabilities to perform the operator skills required by forward area air defense weapons, and (b) to identify effective training concepts for developing these skills. The state of knowledge concerning the soldier's ability to accomplish these functions is summarized in the following sections.

Aircraft Detection and Recognition

Detection. Field tests conducted by HumRRO in 1965 used a 30° search sector and had early warning of the type that could be provided by forward observers equipped with radios (2, 3). These tests revealed that jets were detected, on the average, at 11,100 meters, and liaison-type aircraft were initially seen at 8600 meters. In contrast, tests conducted earlier by the U.S. Army Human Engineering Laboratories indicated that observers given a 45° search sector and no early warning detected aircraft, on the average, at 2750 meters (4). When the search sector was increased to 90° and 360°, the detection range correspondingly decreased to 2586 and 1985 meters.

Recognition. Only two recent tests have been conducted on aircraft recognition. The Human Engineering Laboratories study discussed above found that aircraft were recognized, on the average, at 1170 meters. In contrast, the HumRRO tests showed that recognition occurred, on the average, at 2900 meters, presumably because the aircraft were initially detected at a greater distance. Additional field testing of aircraft recognition would be desirable, but the considerable difficulty and expense of scheduling field tests involving 12 to 15 different types of aircraft tends to outweigh the value of the new test data that would be obtained.

Optical Aids. Several studies have explored the use of monocular and binocular optics as aids to detection and recognition. When the exact point at which a target would appear was known, detections were increasingly aided as optical magnification increased (5); however, the same study recommended that, when factors such as vibration and atmospheric shimmer must be considered, a low-power (3x) optical aid be used for detection. When the target's point of appearance was not known—that is, when the detection task also involved search—SKYFIRE studies have shown that detection was not facilitated with optical aids of six or seven power (2). In contrast, recognition range was increased by using optical aids in several studies (2, 3, 5).

Aircraft Recognition Training

Previous HumRRO research, conducted under Work Unit STAR, found that the training methods used during World War II could be greatly improved upon, and that the amount of time required to learn to name aircraft accurately exceeded the time allocated by the current Army Subject Schedules (6).[1] At the present time, the U.S. Army Air Defense School has revised its training concepts to adopt the training procedures and training aids developed under the STAR research[2] (this research is currently investigating

[1] Department of the Army. *Visual Aircraft Recognition*, Army Subject Schedule 44-2, Washington, September 1964.

[2] Department of the Army. *Visual Aircraft Recognition*, Field Manual 44-30, U.S. Army Air Defense School, 1968.

training methods suitable for self-instructional use during unit training and for the maintenance of recognition abilities by deployed personnel).

Range Estimation

Other research under Work Unit SKYFIRE has been concerned with methods of improving gunners' judgments of the distance to aircraft. The objective was to increase the accuracy of estimating when the aircraft is within the effective zone of fire for the weapon (7). This research found that the most accurate method of judging the open- and cease-fire ranges involved the use of simple ranging aids, such as the finger occlusion method used by M60 machinegun operators. For the rifleman, it was found that the front sight guards of the weapon can serve as an effective ranging aid.

This research also indicated that such training could be accomplished without using full-size aircraft; model aircraft that could be moved along a wire or carried on booms attached to a truck proved to be valid training aids.

Lead Angles for Various Flight Path Distances

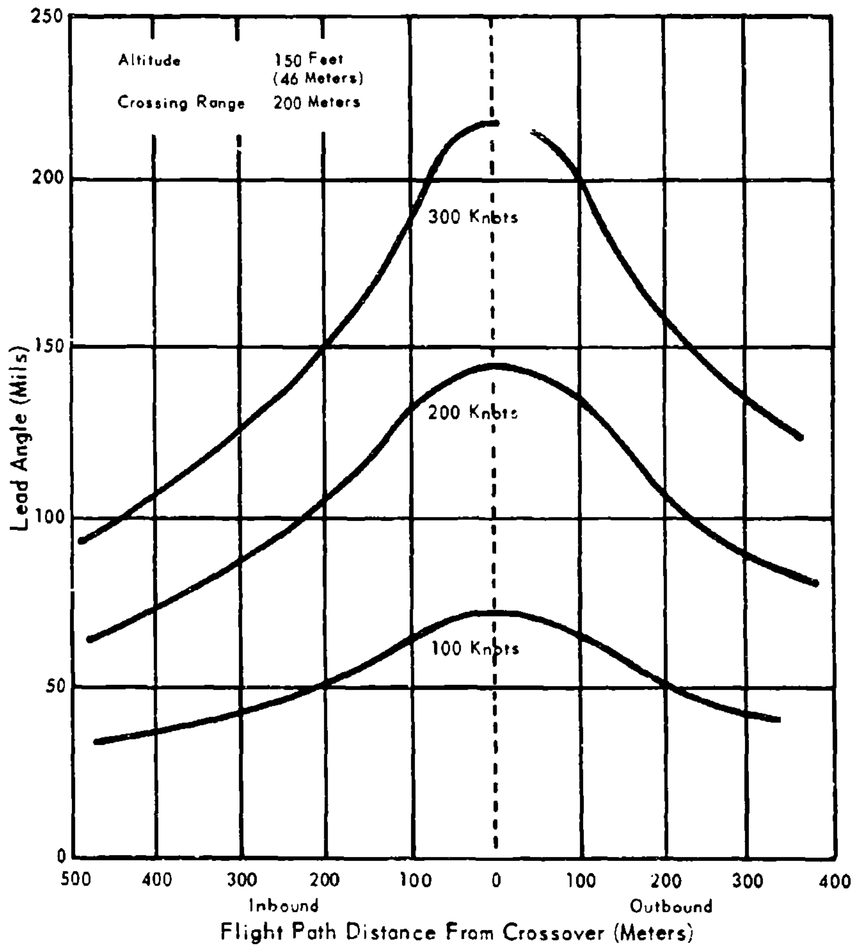


Figure 1

Lead Estimation for Infantry Weapons

Leading the Target. When a target is moving tangentially to a gunner's position, the gunner's aimpoint must be ahead of the target to compensate for the differences in the relative velocities of the target and the projectile. If the target was flying a circular course around the observer's position at a constant speed, the amount of lead required would be constant. Since targets seldom fly circular courses, the correct lead required for a hit constantly changes. Figure 1 presents the angular leads required for hits on aircraft at an altitude of 150 feet, a crossing distance of 200 meters, and speeds of 100, 200, and 300 knots when firing 7.62mm ammunition. These leads may be expressed in terms of apparent aircraft lengths, as shown in Table 1.

Table 1

Lead Distance in Aircraft Lengths

Gunner-to-Target Range (meters)	Lead (Aircraft Lengths)[a]		
	100-Knot Target[b]	200-Knot Target[c]	300-Knot Target[d]
205	1.0	2.5	3.0
210	1.0	2.5	3.0
220	1.5	2.5	3.5
250	1.5	3.0	3.5
300	2.0	3.5	4.5
400	2.5	5.0	6.0
500	3.0	6.5	8.0

[a]Stated in apparent lengths to the nearest half length.
[b]UHI-A Helicopter, 12.2 meters long.
[c]OV-1A Mohawk, 12.5 meters long.
[d]F-100 Super Sabre, 14.6 meters long.

Lead Angles in Relation to Slant Range

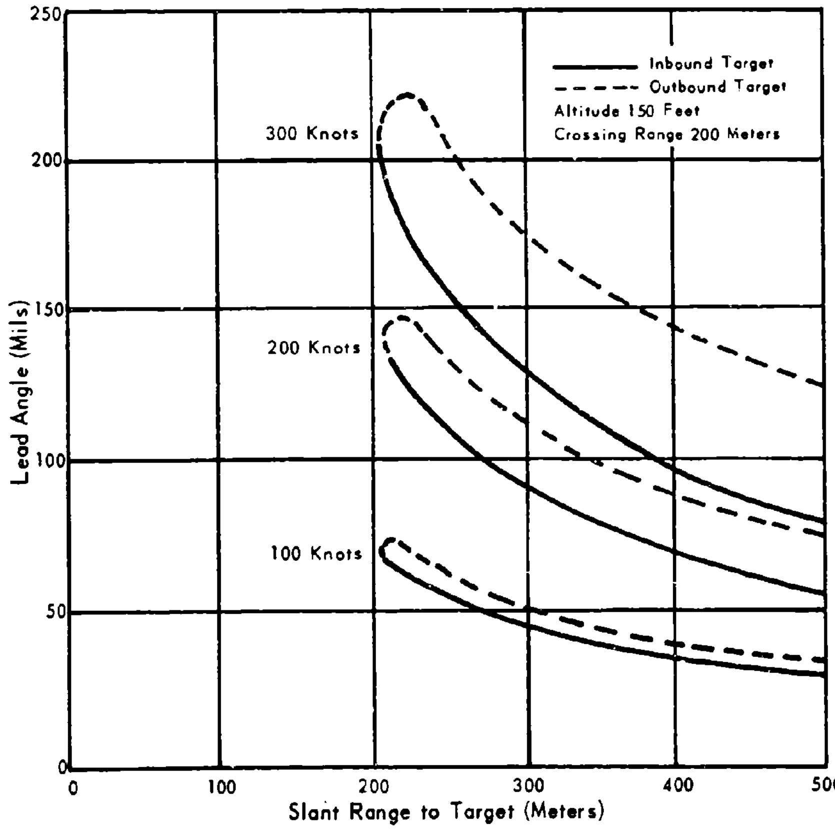


Figure 2

Japanese Antiaircraft Sight

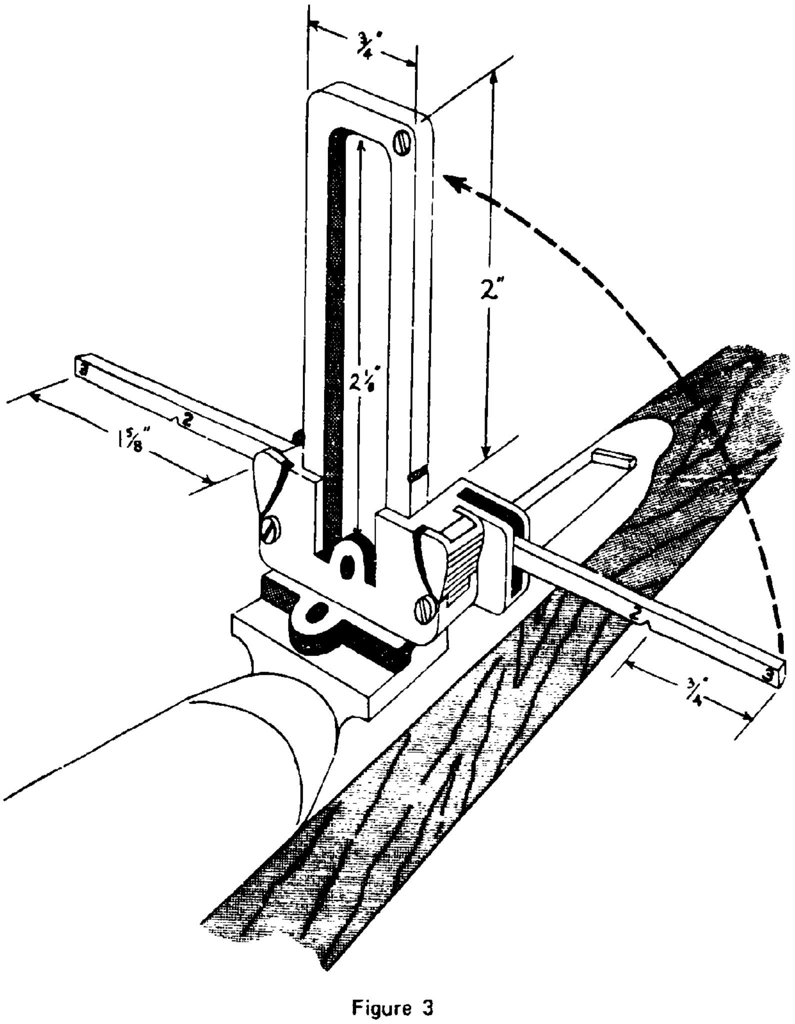


Figure 3

The angular leads are plotted in Figure 2 as a function of gunner-to-target range or slant range. This figure shows, for example, that a lead of 129 mils is required for a 300-knot aircraft when the aircraft is inbound at a slant range of 300 meters. However, when the same aircraft is outbound at 300 meters, a lead of 176 mils is required.

Sighting Aids. The use of shoulder-fired weapons might be facilitated by provision of special air defense sights. For aerial marksmanship, the North Vietnamese reportedly have used a simple bamboo rear sight, attached to the side of the rifle stock. The sight has three apertures; the hole, nearest the stock is used for firing at helicopters, the middle hole is used when engaging fixed-wing targets, and the outside hole is used when firing at high performance aircraft. A similar auxiliary feature was designed into the rear sight of at least one model of Japanese rifle used during World War II. The Japanese sight is shown in Figure 3.

Concepts of Antiaircraft Sight for M14 Rifle

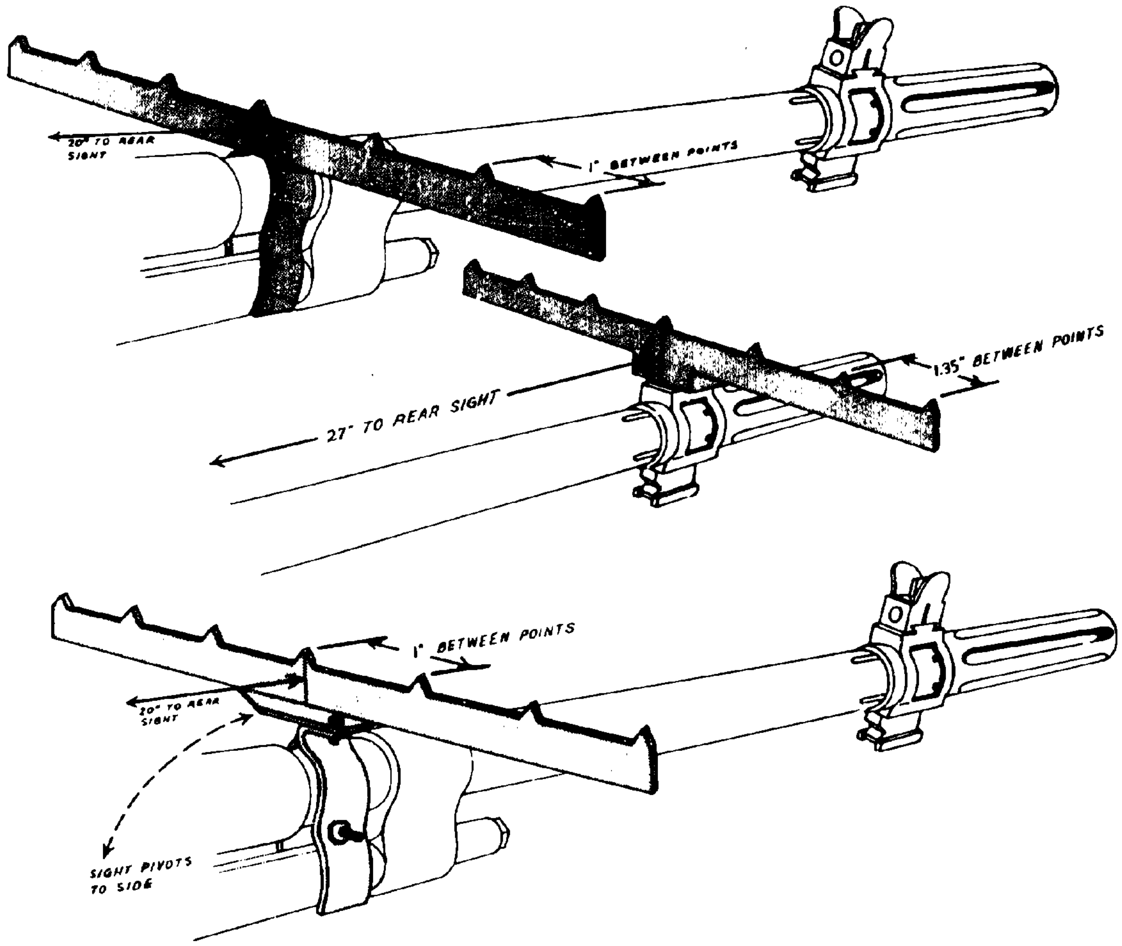


Figure 4

Three concepts for a clip-on auxiliary front sight for the M14 rifle, developed by the engineering staff of HumRRO Division No. 5, are shown in Figure 4. The three sights are designed so that the points of each sight represent 50, 100, and 150 mils deflection from the centerline of the weapon's bore when sighting over the rear peep sight. This type of sight would be very inexpensive to produce, and might be included in cases of small arms ammunition to permit easy replacement of lost or damaged auxiliary sights.

These sights could be used most effectively with the Fly Through Technique (described in the following paragraphs), but they also might have successful application with the Changing Lead Technique by having the rifleman switch from one sight point to the next as the aircraft's range decreased. The extent to which auxiliary air defense sights would aid marksmanship needs to be evaluated.

Techniques of Engagement

Engagement of a rapidly moving target by an infantry weapon is a unique problem in marksmanship, since the aimpoint is an area in space ahead of the aircraft. Obviously, selecting the correct aimpoint involves determining the amount of lead plus the amount of superelevation (if any) necessary to place the projectile at the area in space which will be occupied by the target. While superelevation of the weapon's barrel to compensate for the force exerted by gravity is required in most of the gunnery situations considered here, it can be ignored as a problem since the target's presented area is large, and the ballistics of infantry weapons have an essentially flat trajectory within the effective zone of fire against aerial targets.

Although the soldier using small infantry weapons need not be concerned with superelevation, he does need to establish an imaginary line in space which represents the future flight path of the aircraft. The gunner must continuously extrapolate the target's present line of flight and continuously adjust his aimpoint to provide the appropriate lead along this extrapolated line while firing. This technique of firing will be called the *Changing Lead Technique.*

A simplification of the Changing Lead Technique is the *Fly Through Technique*, which involves establishing an arbitrary but constant lead along the line of flight, and firing continuously. If (a) the arbitrary lead selected by the gunner is among the set of leads appropriate for the target speeds and target-to-gunner distances, and (b) there is sufficient ammunition in the weapon, the target will fly into the projectile stream twice—once while inbound, and once while outbound.

A second alternative is known as the *Pattern of Fire Technique*. As normally employed, this requires *several* weapons firing simultaneously and continuously at a common and fixed area in space ahead of the target. Again, if the area to be fired at is established well ahead of the target—beyond the ballistically correct lead angle—and ammunition is sufficient, the target will fly into the pattern of fire.

Although all three techniques of aerial firing have been used under various conditions, the relative efficiency of the three methods is not known. Current Army doctrine, as presented in Field Manual 7-15,[3] is to employ the Changing Lead Technique against low-performance (less than 200 knots) aircraft and to employ the Pattern of Fire Technique against high-performance targets. The Fly Through Technique was the basis for the design of fire control directors and computing sights used on light antiaircraft weapons during and after World War II. It has never been applied as doctrine for small arms.

[3] Department of the Army. *Rifle Platoon and Squads: Infantry, Airborne, and Mechanized,* Field Manual 7-15, March 1965.

The Pattern of Fire Technique is the simplest to employ, since it requires all weapons to fire at a single area ahead of the target. The Fly Through Technique is more complicated since, to be effective at all, it requires the gunner to maintain a constant lead and fire continuously on inbound and outbound courses. The Changing Lead Technique is the most difficult, because it requires the gunner to continuously change his lead depending upon the aircraft's present position.

However, when the number of hits per 100 rounds fired is considered, the Changing Lead Technique appears to be the most efficient, *if* the gunners can learn to change leads correctly. On the other hand, if gunners cannot learn to establish the approximately correct changing leads, the method in effect becomes the Fly Through Technique, as long as gunners are able to continue firing on both the inbound and outbound courses. Although the Pattern of Fire Technique appears to be the simplest, it does require coordination and communication among gunners concerning the selected fixed aiming area. No tests have been made of the relative effectiveness of the three techniques.

A fourth technique involves use of tracer ammunition to determine the correct lead by observing the bullet's position as it "burns." *Tracer Observation* usually is employed with the Changing Lead Technique, although it could be used to advantage with any technique, at least to determine whether the projectiles are intersecting the line of flight of the target. It has been traditionally assumed that tracer observation provides the gunner with knowledge of results (feedback) concerning the projectile's path in relation to the position of the aircraft. That is, tracer observation has been used to determine the lead as well as the line.

However, the results of a recent study conducted by HumRRO under Work Unit TESTAID have cast doubt on the usefulness of tracer observation for antiaircraft fire control (8). This study pointed out that the time of flight of the projectiles causes a time delay in the feedback provided to the weapon operator. Since a gunner tends to continuously change the amount of lead as he fires, this delay in feedback potentially could confuse the weapon operator more than it aids him. In addition, it is well-known that the illusions of "apparent tracer stream" and "tracer hump" also produce errors in sensing the location of tracer fire with respect to the aircraft.

TRAINING REQUIREMENTS

As implied by the preceding discussions, aerial marksmanship is a complex task, with the gunner's accuracy being influenced by a number of factors:

(1) His ability to estimate the range to the target.
(2) His ability to estimate both the correct lead and the correct line in order to establish an aimpoint.
(3) His ability to track the aimpoint, continuously and smoothly.
(4) His ability to establish a rate of fire for his weapon that minimizes the extent to which recoil will interfere with smooth tracking.

Each of these component skills must be trained to a high level if aerial marksmanship is to be effective. Obviously, the specific content and amount of training given for each component skill will depend upon the technical characteristics of the weapon being taught.

In designing effective training, attention must focus on the relevance (the validity) of the training experiences to characteristics of the tactical situation. As stated previously, the tactical parameters of greatest importance to marksmanship are the range of the target, its rate of movement and size, and the ballistic time of flight of the projectile; these are the characteristics that, in combination, determine the correct lead required for

a hit. These parameters and their interrelationship must be faithfully represented in training in order for the training to be effective.

Two methods of representing these parameters seemed the most applicable:

Range Facilities for Live Firing. One method of maximizing relevance in training is to use full-scale duplication of the critical target and weapon characteristics. For those types of targets appropriate to 7.62mm weapons, the use of full-scale aerial targets, speeds, and ballistics is feasible, although the cost of full-size targets and the necessary range facilities would be high.

An alternative is to use towed targets, such as the traditional sleeves and banners. Although these targets are relatively inexpensive, extensive firing ranges are required and it is not possible to give immediate feedback to gunners concerning firing results. The radio-controlled aerial target (RCAT) is another possible alternative, but the device is much smaller than a tactical aircraft; thus, it offers an unrealistically difficult target for a rifleman.

Miniaturized Facilities. In addition to miniaturizing just the target, it is possible to scale down all the critical factors—speed, size, distance, and ballistic time of flight. As long as all factors are miniaturized by the same proportion, the leads and firing situations will be accurately represented. For example, by reducing by one-third the target's speed and size and the projectile's time of flight, the lead required for a hit at a distance of 300 meters under full-scale conditions would be the same as that required at 100 meters on the training range. Miniaturization thus could reduce problems associated with providing high-speed targets and extensive range facilities.

The big problem in miniaturizing this situation concerns the feasibility of reducing the muzzle velocity of the ammunition, without interfering with the mechanical functioning of the automatic weapons. However, subcaliber weapons have been used for training in the past. Caliber .22 long rifle conversion units were available at one time for the caliber .30 light machinegun (9), and a compressed-air device for training caliber .50 heavy machineguns also was used during World War II (10). In addition, portions of the training sequence for live firing training of tank gunners have used subcaliber weapons to reduce training costs (11).

RESEARCH APPROACH

This introductory chapter has reviewed characteristics of the forward area air defense problem as it pertains to the light weapons infantryman and summarized the state of knowledge concerning the operator skills required and the engagement techniques that may be appropriate for use of small arms against low-flying aircraft.

The review of research and study findings indicated that human performance data and techniques for effective training have been developed for the following critical skills: visual detection, visual aircraft recognition, distance estimation, and techniques of engagement. However, although performance data and training and operational techniques were available for each skill requirement, training programs had not been devised that would implement the integration of these job requirements.

In the present research, two approaches were developed for training infantry personnel to engage aircraft. Chapter 2 describes a method that used full-scale range facilities but did not involve live firing during training. Chapter 3 describes a miniaturized training facility and method that used a subcaliber weapon during training.

Chapter 2

A FULL-SCALE TRAINING PROGRAM

RESEARCH REQUIREMENT AND APPROACH

At the request of the U.S. Army Infantry School (USAIS), HumRRO conducted a study of the use of infantry weapons (small arms) in an air defense role.[1] The purpose of the study was to develop an experimental training program that would provide information concerning objectives of instruction, content, and duration of training needed to give infantrymen a capability for engaging low-flying aircraft with small arms. This chapter describes the results of the content analyses and outlines tests which were performed to evaluate the validity of the analyses and determine the length of training needed.[2]

The content of the experimental training was based on a psychological analysis of the skill components involved in firing at aerial targets. The experimental content was *not* based on extensive experimental tests, although the non-firing portions of the recommended training were given a preliminary test by HumRRO at Fort Bliss, Texas. This advance testing was conducted to determine the amount of training time needed for developing specified skill levels among trainees, and also to provide information concerning the validity of the skill analyses.

The complete program, with an application of the training in a final live firing phase, was subsequently demonstrated at Fort Benning, Georgia, during January 1966. Two groups of eight trainees each were trained by means of the eight-hour program.

DEVELOPMENT OF TRAINING PROGRAM

Skill Requirements

Analysis of the task of engaging a moving aerial target with a shoulder-fired weapon reveals four important skills: range estimation, lead estimation, manual tracking, and weapon operation. Of these four skills, range and lead estimation were judged to be the most important and were given the greatest emphasis in the development of the experimental training.

Training in Range Estimation

Training Objectives. The rifleman must be able to accurately estimate when the target is within 350 meters, the distance assumed to be the effective range of his weapon against aircraft.

[1] Letter, AJIIS-D, Headquarters, U.S. Army Infantry School, dated 13 July 1965, Subject: Development of Techniques and Training Requirements for Use of Organic Infantry Weapons in an Air Defense Role.

[2] The effort was limited to training experimentation, without use of special sighting or ranging aids, because of the long lead time needed to obtain new equipment items on an operational basis.

When the target is near the ground, the rifleman can use terrain features at known distances as aids in estimating range. When the target is at higher altitudes, terrain cues become less available, and the rifleman needs to be able to use other cues to estimate target range.

Proficiency Standard. Previous test results (7) had indicated that untrained persons estimate range with an approximate error of 25%, and that with training the error can be reduced to about 10% of the effective range. An aircraft flying at 150 knots at low altitude (100 feet) will be within firing range, incoming and outgoing, for approximately 10 seconds. It is assumed that the semi-automatic weapon will be fired at the rate of about one round per second. Therefore, if the rifleman estimates the target to be in range too soon (i.e., estimates it to be at 250 meters when it is beyond that range) and fires upon it at that time, one round will be wasted for every 75 meters error of estimation. An error of 75 meters is about 22% of the effective firing range. An aircraft flying at 75 knots travels at about 37 meters per second; an error of 35 meters is 10% of the effective range.

A proficiency standard of 10% error for seven of the eight trainees in a training group was established as the goal of instruction during the research, which would approximate a 90% criterion in operational training.

Training Procedure. Prior to the first training period, the trainees were given simple guidelines to assist them in estimating the 350-meter range. The guidelines were in terms of the number of fingers that will occlude aircraft at 350 meters. The trainees then practiced range estimation during a series of training and test periods.

A training period consisted of observation of six aircraft flights. For each training trial the instructor announced when the aircraft was approaching 350 meters, and when it was at 350 meters, for both incoming and outgoing directions.

Immediately after each set of six training trials, a two-trial test period began. The target aircraft flew the same flight paths for testing as for training. During the test trials, the instructor counted from one to 30 at a rate of one numeral per second while the aircraft approached, passed through, and moved out of firing range. The counting began when the aircraft was approximately 750 meters from the trainees; the actual range of the aircraft at the time the counting began varied from trial to trial. Each trainee was instructed to record the number being announced when he estimated that the aircraft entered and left the effective range (350 meters).

After the aircraft's pass was completed, the instructor called out the correct numerals. These were obtained from range-marking assistants positioned at 350 meters along the inbound and outbound portions of the flight path and netted with the instructor by field phones; they recorded the numeral announced by the instructor at the time the aircraft flew over each 350-meter position. The true ground speed of the aircraft was checked by a dead-reckoning procedure.

The training and testing cycle was repeated until seven of the eight trainees in a group had an error of 10% or less of the correct range for two successive trials.

The aircraft flew at a speed of 100 knots over four parallel courses, with the altitudes varying between 75 and 300 feet at each of four crossing ranges of zero, 100, 200, and 300 meters. The altitudes and crossing ranges for each pass were randomized, and the aircraft flew equal numbers of courses from both directions. The physical measurements of the flight courses are shown in Table 2. A schematic diagram of the facility is presented in Figure 5.

Table 2

Range Facilities for Distance Estimation Training

Flight Course Number	Crossing Range (meters)	Terrain Distance (meters)[a]
1	0	1000
2	100	1000
3	200	1000
4	300	1000

[a]Distance between panel markers at end-points of course.

Schematic Diagram of Range Estimation Training Facility

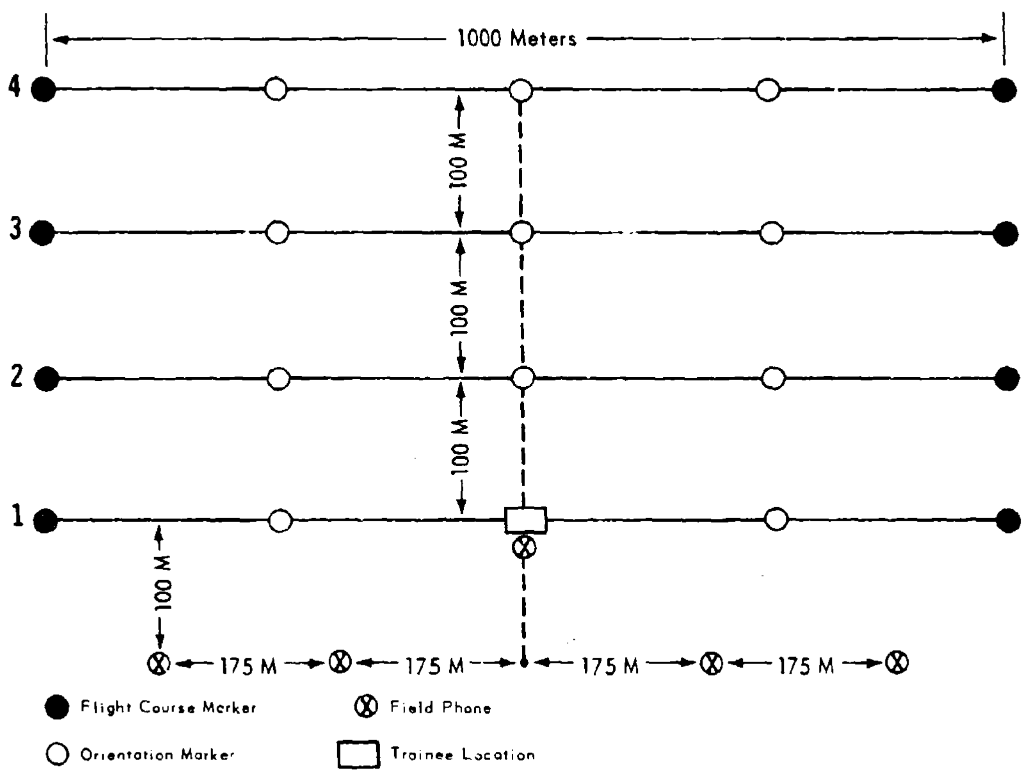


Figure 5

Training in Lead Estimation and Tracking

Training Objectives. Lead estimation requires the rifleman to establish an aimpoint ahead of the target and to continuously and accurately track this point in space while operating his weapon. Because of the dynamic nature of the geometry which characterizes antiaircraft firing, the correct lead continuously changes. This skill is difficult to learn because the correct lead depends primarily on the rate of movement of the target relative to the rifleman and the target's distance.

However, training can be simplified if the instruction concentrates on teaching the two or three leads that are correct for *most* of the targets that the rifleman should attempt to engage. The job requirement then would involve selecting the lead most appropriate for the specific tactical circumstances. This method essentially is the Fly Through Technique, which is the concept behind the design of the computing sights used with larger-caliber antiaircraft weapons during World War II.

Proficiency Standard. The level of proficiency required was for seven of the eight trainees in a training group to be able to track an aircraft accurately for 75% of the flight course.

Training Procedure. The training began with teaching the concept of lead, during a conference in which typical engagement situations and the two or three "best" leads that

Tracking Board

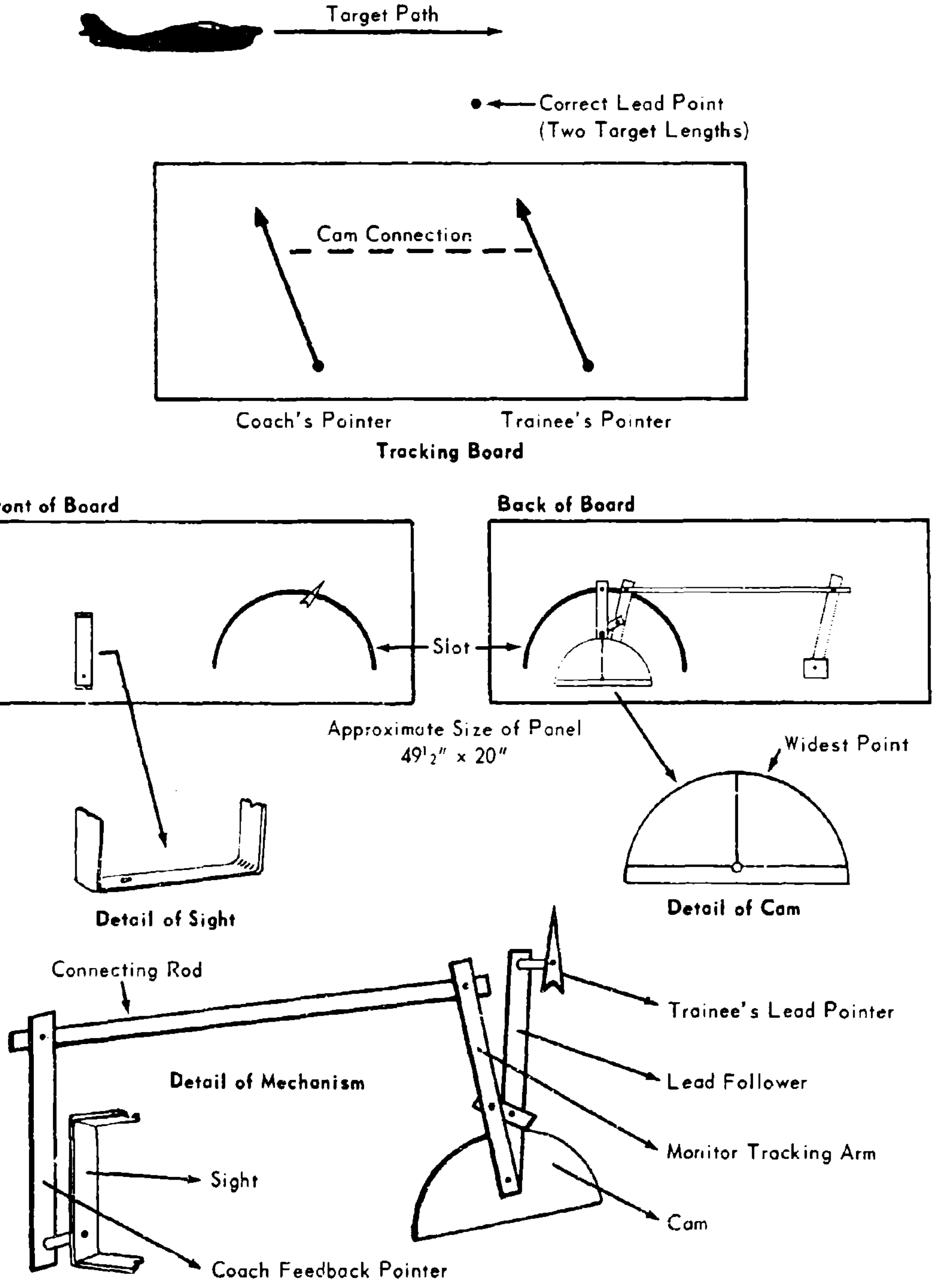


Figure 6

the rifleman must learn were described. Practice was then given in estimating the lead appropriate for various target speeds and distances.

This training was given on a simple-to-construct training device designed to provide continuous feedback to the trainee concerning the correctness of his lead estimate. One version of this device is illustrated in Figure 6. When the trainee positioned the "Lead Pointer" on the device at the correct lead, the "Feedback Pointer" pointed to the target. In training with the device, trainees were paired and alternated as "Pupil" and "Coach." The trainee positioned the "Lead Pointer" as he desired, and the coach, observing the position of the "Feedback Pointer," told the trainee whether he was correct or was over- or under-leading.

Training, using this device, proceeded in the following sequence:

(1) Practice was given in estimating specified leads, using as a target a stationary wheeled vehicle, located at a distance of 100 meters.

(2) Practice was given next in tracking the specified leads, using as a target a moving wheeled vehicle, which traveled at a speed of 45 mph at a minimum crossing distance of 100 meters.

(3) Practice next was given in selecting and tracking the correct lead, using an aircraft as a target. The aircraft flew at speeds of 75 and 125 knots at crossing ranges varying from 100 to 300 meters.

The range facilities which had been used for range estimation training were also used for the lead estimation training. The training was continued until seven of the eight trainees accurately tracked an aircraft 75% of the flight course during two successive passes.

LIVE FIRING PHASE

The preliminary testing of aspects of the training at Fort Bliss did not involve live firing. This phase of the activity was conducted at Fort Benning, as the final phase of the demonstration of the training program.

When individual training in each of the two training phases had been successfully accomplished, the eight trainees in a training group were required to apply these skills by firing as a "squad" at an aerial target with the M14. Estimation of range was required, as well as the estimation of the proper lead and accurate tracking of the target while firing.

The target consisted of a sleeve target, towed at a speed of 100 knots at a 100-foot altitude and at 100- and 200-meter crossing ranges.

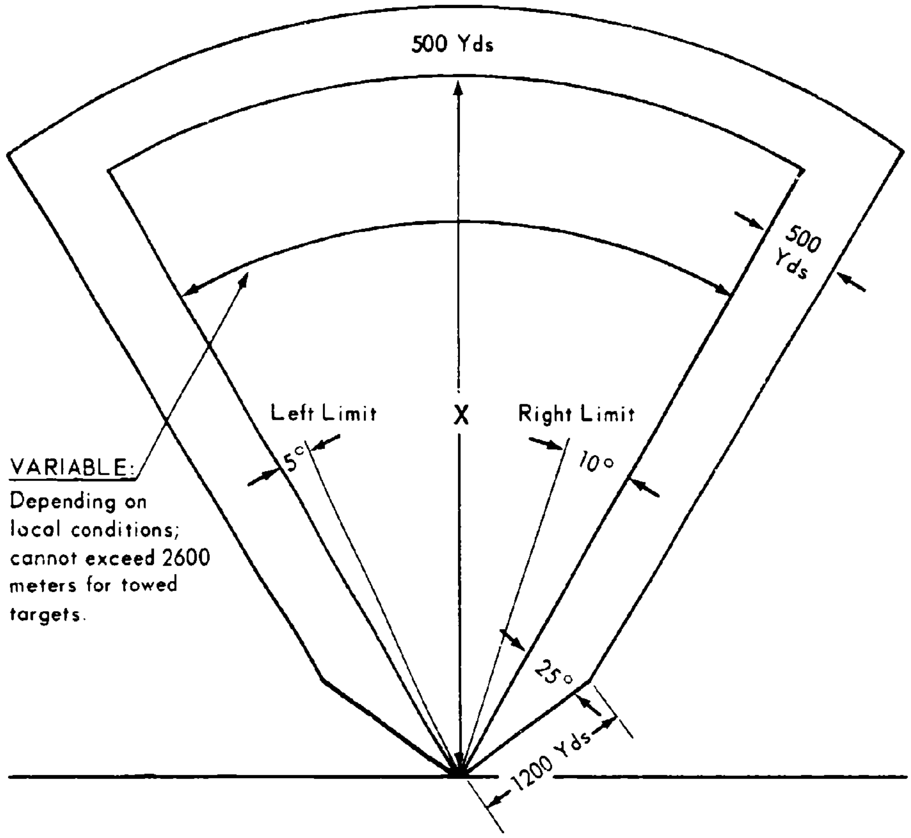
SUPPORT REQUIRED

Range Facilities

(1) Distance and Lead Estimation Facility. A relatively flat area one mile long and 500 meters deep was required for the range and lead estimation training. This area contained a road having a straight section, approximately 1200 meters in length, which could be driven at 45 mph.

(2) Small Arms Aerial Target Range. The range at Fort Benning was capable of permitting live firing with the M14 over an angle of 2600 mils at a maximum gunner-to-target crossover distance of 200 meters. The terrain permitted an aircraft to tow a sleeve target at a constant altitude of 200 feet for a total distance of 1800 meters. The safety diagram for this range is shown in Figure 7.

Safety Diagram for Antiaircraft Small Arms and Machine Guns



Notes

X = Max Ground Impact for Weapon Firing for 7.62mm = 3725 m

Aerial Towing:

A - Minimum Tow Line - 600 yds or equal to target speed X max time of flight

B - Minimum Gun - Target - Aircraft Angle - 300 meters

SOURCE: Extract from Army Regulation 385-63, Regulations for Firing Ammunition for Training, Target Practice, and Combat.

Figure 7

Aircraft. Two types of aircraft were required for the training demonstration. Approximately eight hours of flight time by a U6-A was needed in support of the distance and lead estimation training. In addition, a U.S. Navy US-2C was required for towing a sleeve target at a speed of 100 knots at an altitude of 200 feet.

Weapons. Twelve M14 rifles and four M14 E2 automatic rifles were required for firing on two days. The first live firing was conducted on a TRAINFIRE training range to provide refresher training for the 16 men who participated in the demonstration of the training method. The second live firing occurred during the final period of the aerial marksmanship program.

Training Devices. The Infantry School constructed seven "Lead Training Boards," based on plans and a full-scale prototype provided by HumRRO. The lead compensation cams which controlled the relationship between the lead and feedback pointers were provided by HumRRO for all the boards. The rest of the device was constructed of easily obtainable wood and metal parts.

Personnel. Two groups of eight men who had completed basic rifle marksmanship training were required for the training demonstration. The subjects had 20/20 vision and were between the ages of 18 and 26 years. They were required for eight hours per day for two successive days.

Personnel needed to assist in administering the training and test included (a) four enlisted men for one-half day to serve as range marking assistants for the aircraft flights; (b) two enlisted men for one-half day to serve as road guards for the lead estimation training involving the moving vehicle; (c) one vehicle operator for one-half day; (d) one officer and staff to administer the live firing test.

RESULTS OF LIVE FIRING PHASE

The first group of eight trainees to fire—using seven M14 rifles and one M14 E2—fired 470 rounds of 7.62mm ball ammunition and achieved three hits on the target. It became obvious that the trainees tended to aim directly at the target rather than at the proper lead point.

Before the second group fired, they were reminded that they should lead the target as they had learned the day before. They fired 490 rounds and achieved seven hits on the target.

The hit data were evaluated with reference to an O-1A (formerly designated L-19). Hit data from the small MK-23 target, scaled to the O-1A aircraft on the basis of relative area, would result in 38.4 hits for the 960 rounds fired, or about 4%. This compares favorably with the hit proportions obtained in live firing tests by the U.S. Army Combat Developments Command (12).

SUMMATION

This approach to training for small arms engagement of aerial targets employed full-scale facilities for teaching distance estimation and leading and tracking skills. The distance estimation judgments used stadimetric techniques (the occlusion method), with an Army liaison aircraft used as the training target. The leading and tracking training used a specially constructed coach-pupil training device and employed moving ground vehicles as well as actual aircraft.

Although no live firing was included in the small arms training program, it was found that trainees, tested after completing the non-firing instruction, achieved an average hit rate using the service rifle which was consistent with previous test results involving considerable amounts of live firing.

Chapter 3

A MINIATURIZED TRAINING METHOD

RESEARCH REQUIREMENT AND BACKGROUND

In the second quarter of FY 1967, the U.S. Army Infantry School requested assistance in the development of training techniques and a miniaturized range for training the skills necessary to engage aerial targets. A program was desired that would train up to 200 men during one six-hour training period. It was specified that, if at all possible, all aspects of the training program should be conducted using miniaturized facilities and no full-scale aircraft.

Other research performed under Work Unit SKYFIRE (7) had included an analysis of reduced-scale and miniaturization requirements for air defense training programs. The ballistics of several potential subcaliber weapons had been examined, and previous miniaturized training facilities for firing practice were analyzed. As a result of this research, it had been concluded that the ballistic characteristics of the air rifle (BB gun) seemed the most suitable for use on a miniaturized range.

The concept underlying the use of a scaled range involves reducing the size of the real-world target situation for economy and space considerations. However, certain important aspects of aerial fire must be retained so that the soldier will receive valid training. The two most important parameters to be retained from the full-size target situation are the angular target velocity with respect to the firer and the amount of lead appropriate to each value of angular velocity.

A BASIS FOR MINIATURIZATION

The real-world gunnery problem to be miniaturized can be described with the help of the diagram shown in Figure 8. A target flies a straight line course from point P to point P_f with constant velocity U and approach angle α. The point P_f represents the position of the target at the time of impact with a suitably aimed projectile fired from a gun when the target is at P; P_f is called the future position of the target. The distance from the gun to P is the present range at the instant of fire and is denoted by R. The distance from the gun to P_f is the future range and is denoted by R_f. Let V_f be the average velocity of the projectile over the range R_f and let T_f be the time of flight of the projectile over R_f. Introducing averages makes the projectile velocity constant and permits the use of the formula, "distance is equal to velocity multiplied by time." Finally, let the angle Λ from the gun target line $\overline{GP}$ to the gun impact line $\overline{GP_f}$ be the kinematic lead angle required for impact.

Applying the law of sines to the triangle GPP_f gives

$$\frac{\sin \Lambda}{\sin \alpha} = \frac{\overline{PP_f}}{R_f} = \frac{UT_f}{V_fT_f} = \frac{U}{V_f},$$

Diagram of Real-World Gunnery Problem

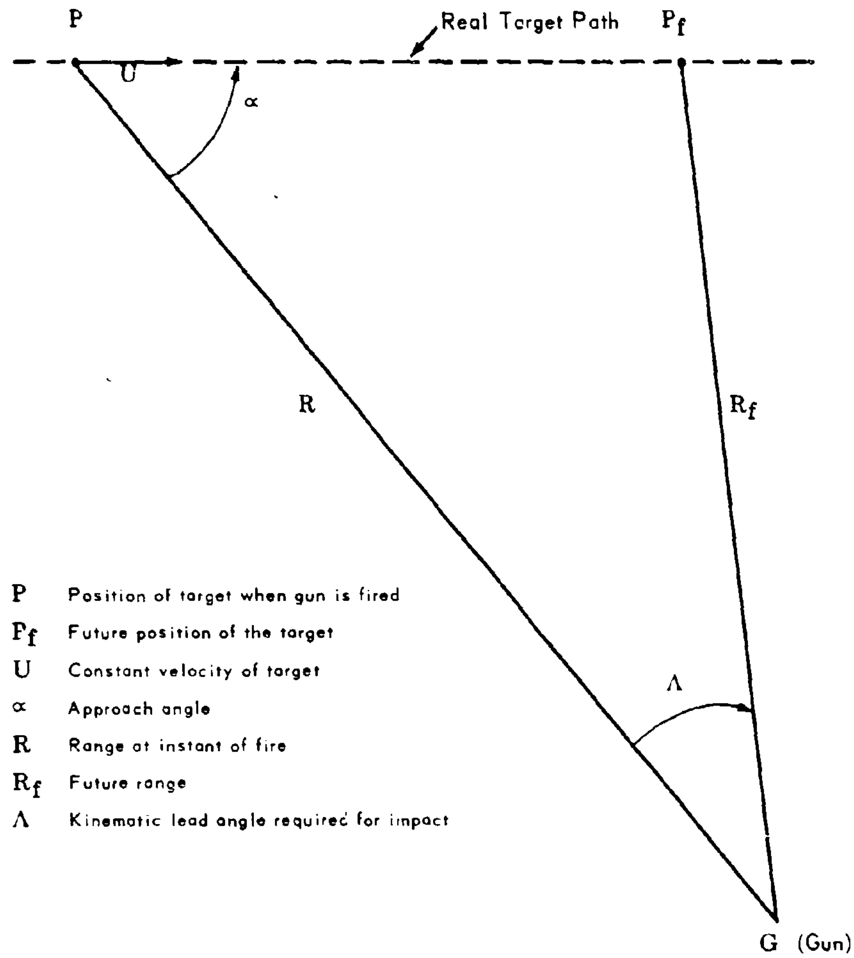


Figure 8

so that the sine of the kinematic lead angle is

$$(1) \qquad \sin \Lambda = \frac{U}{V_f} \sin \alpha .$$

Equation (1) is the basic relation required for the kinematic lead but it is not useful because it contains the quantities U and α which are not directly available as inputs to the gun. The equation has to be modified into an approximate form involving only present data. To this end, let Ω be the angular velocity in radians per second of the gun target line $\overline{GP}$. Then, by resolving the target velocity vector into perpendicular and parallel components with respect to GP, the angular velocity can be expres

$$(2) \qquad \Omega = \frac{U}{R} \sin \alpha .$$

If equations (1) and (2) are combined, the sine of the kinematic lead is given by

$$(3) \qquad \sin \Lambda = \frac{R\Omega}{V_f} .$$

Let V_R represent the average velocity of the projectile if the projectile had to travel over R instead of over R_f. Multiply and divide the right-hand side of equation (3) by V_R to obtain

$$(4) \qquad \sin \Lambda = \frac{V_R}{V_f} \frac{R}{V_R} \Omega .$$

Because V_R is constant, the ratio R/V_R in equation (4) can be replaced by T_R, the time of flight of the projectile over the range R. With this replacement, equation (4) becomes

$$(5) \qquad \sin \Lambda = \frac{V_R}{V_f} T_R \ \Omega .$$

If R_f does not differ greatly from R, the ratio V_R/V_f in equation (5) is approximately equal to unity and the equation can be written

$$(6) \qquad \sin \Lambda = T_R \ \Omega .$$

A further approximation can be made if the kinematic lead angle is small. It can be shown that if $\sin \Lambda$ is replaced by Λ (in radians), then the absolute error is less than $0.17\Lambda^3$. Making this replacement in equation (6) then gives the useful approximation for the kinematic lead angle,

$$(7) \qquad \Lambda = T_R \ \Omega .$$

The first step in constructing a miniaturized gunnery problem is to reduce the length of the present range R of the real world problem. Thus, let k be a number between 0 and 1 and call it a scale reduction factor. Define r, the present range of the reduced problem, by

$$(8) \qquad r = kR .$$

(In what follows, lower case letters designate the parameters of the miniaturized gunnery problem.) The scaled-down target (whose dimensions will be discussed later) is assumed to fly a straight-line course parallel to the real world target course. The situation is depicted in Figure 9. The scaled-down target flies along the line joining q and q_f and this line is parallel to the line joining P and P_f of Figure 8. By the definition of r, the line segment joining G and q, the gun target line, is a portion of the gun target line GP of Figure 8. The approach angle is thus the same for both gunnery problems. The point q_f is the position of the miniaturized target at the time of impact with a suitably aimed projectile fired from the gun when the target is at q. The future range of the miniaturized target is r_f, its velocity is u, and the required kinematic lead angle is λ.

The triangle Gqq_f thus defines the miniaturized gunnery problem. An argument identical to that which led to equations (2) and (7) can be applied to the reduced problem to give the corresponding pair of equations

$$(9) \qquad \omega = \frac{u}{r} \sin \alpha ,$$

$$(10) \qquad \lambda = \omega t_r$$

where ω is the angular velocity of the gun target line $\overline{Gq_f}$.

The next steps in constructing a miniaturized gunnery problem are to discover the conditions necessary for equivalence between the real world and miniaturized gunnery

Diagram of Miniaturized Gunnery Problem

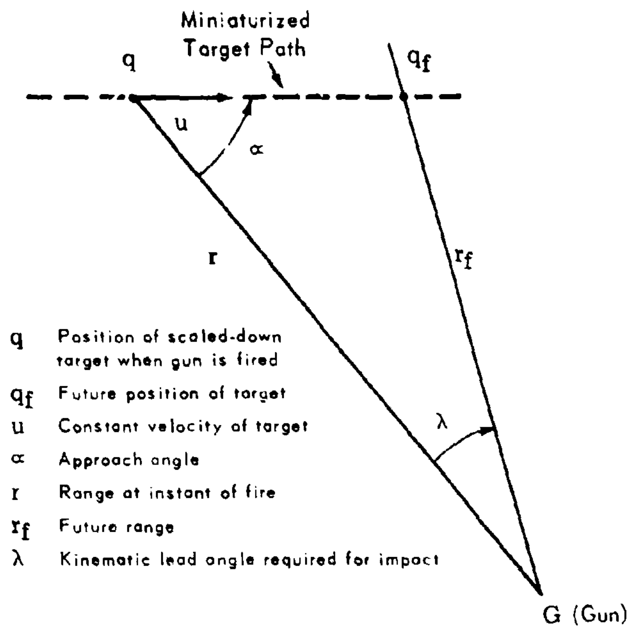


Figure 9

problems. The two problems will be considered equivalent if the target angular velocities are equal, the kinematic leads are equal, and the angles subtended by the targets at the gun are equal.

The conditions for the equality of the two angular velocities, Ω and ω, can be deduced by setting the right-hand sides of equations (2) and (9) equal to each other,

$$\frac{U}{R}\sin\alpha = \frac{u}{r}\sin\alpha \, .$$

In this equation, sin α is common to both sides and can be eliminated. Replacing r by its definition (8) then gives the result

$$(11) \qquad u = kU \, .$$

In other words, if $r=kR$ and if $\omega=\Omega$, then u is given by (11). This result suggests using (8) and (11) as conditions. Thus, if both (8) and (11) are true, then

$$\omega = \frac{u}{r}\sin\alpha = \frac{kU}{kR}\sin\alpha = \frac{U}{R}\sin\alpha = \Omega \, .$$

In summary, if both the present range R and target velocity U are reduced by the same scale factor k, then the angular velocities of the two targets are identical. This result is independent of the approach angle α and target size.

Conditions for equality of the two lead angles Λ and λ can be discovered in the same way. Thus, equating the right-hand sides of equations (7) and (10) gives

$$T_R \;\Omega = t_r \,\omega,$$

and if $\omega = \Omega$ then $T_R = t_r$. This suggests using the conditions $\omega = \Omega$ and $T_R = t_r$ in the ratio Λ/λ. Thus,

$$\frac{\Lambda}{\lambda} = \frac{T_R\,\Omega}{t_r\omega} = 1$$

so that

(12) $\Lambda = \lambda$.

In summary, if the angular velocities of the two targets are equal, and if the time of flight of the reduced projectile t_r is equal to the time of flight of the real projectile T_R, then the two kinematic lead angles are equal. This result is also independent of the approach angle α and target size.

The above condition

(13) $T_R = t_r$

for times of projectile flight can be stated in terms of projectile average velocities. Thus, using present ranges and average projectile velocities over these ranges in equation (13) gives

$$\frac{R}{V_R} = \frac{r}{v_r}.$$

Replacing r by kR in this relation then gives

(14) $v_r = k\,V_R$.

The miniaturization requirements established so far are independent of target sizes. To introduce this factor, let D represent the length of the real world target and d the length of the scaled-down target. The target lengths presented to the gun are not D and d but $D \sin \alpha$ and $d \sin \alpha$ respectively. Let Γ represent the angle (in radians) subtended by the real target at the gun and γ the corresponding angle of the miniaturized target. Then Γ and γ can be computed by

(15) $\Gamma = D \sin \alpha / R$,

(16) $\gamma = d \sin \alpha / r$.

The condition $\Gamma = \gamma$ implies

$$\frac{D \sin \alpha}{R} = \frac{d \sin \alpha}{r}$$

and, using $r = kR$, this reduces to

(17) $d = kD$.

Thus, if the length of the real world target is scaled down by the scale factor k, the two angles subtended by the targets at the gun are equal.

The main results of the preceding arguments can be summarized as follows. The following four conditions

C1: $r=kR$, reduction by k of present range,
C2: $u=kU$, reduction by k of target velocity,
C3: $d=kD$, reduction by k of target length,
C4a: $t_r=T_R$, equivalence of projectile times of flight,
C4b: $v_r=kV_R$, reduction by k of projectile velocity,

give the three results

R1: $\omega=\Omega$, equivalence of angular velocities,

R2: $\lambda=\Lambda$, equivalence of kenematic lead angles,

R3: $\gamma=\Gamma$, equivalence of target subtended angles.

Conditions C4a and C4b are equivalent conditions, in the sense that if one of them is satisfied then the other is satisfied.

Thus, when the above four conditions are satisfied, the miniaturized gunnery problem is equivalent to the real world gunnery problem.

Conditions C1, C2, and C3 are easily satisfied for any choice of scale reduction factor k. The only problem is the selection of a training weapon satisfying condition C4 for a given choice of scale reduction factor k. This amounts to finding a training weapon whose projectile time of flight over the reduced present range is approximately equal to the time of flight of the real world projectile over the real world present range. Result R2, equivalence of kinematic lead angles, is the only result affected by projectile times of flight. By definitions (7) and (10) of Λ and λ respectively, the kinematic lead angle for the reduced gunnery problem can be written

$$\lambda = \frac{t_T \omega}{T_R \, \Omega} \, \Lambda \, .$$

The conditions for miniaturization cause the two angular velocities ω and Ω to equal, so that

(18) $$\lambda = \frac{t_T}{T_R} \, \Lambda \, .$$

Equation (18) states that the kinematic lead angle for the miniaturized problem is directly proportional to the kinematic lead angle of the real world problem where the constant of proportionality is the ratio t_T/T_R.

For the weapons of immediate interest, kinematic lead is more appropriately expressed in terms of target length instead of angular measure. Thus, let L and l denote the kinematic leads expressed in units of length of target for the real world target and for the miniaturized target respectively. These leads can be computed by dividing the angular leads Λ and λ by the angles subtended by the targets, so that

$$L = \Lambda/\Gamma \, ,$$
$$l = \lambda/\gamma \, .$$

A more useful expression for L can be derived as follows:

$$L = \Lambda/\Gamma$$

$$= \frac{T_R \, R \, \Omega}{D \sin \alpha} \quad \text{by (7) and (15)}$$

$$= \frac{T_R \, R \, U \sin \alpha}{R \, D \sin \alpha} \quad \text{by (2)}$$

$$= T_R \, U/D \, .$$

Thus,

(19) $$L = \frac{T_R U}{D}$$

and, in a similar fashion,

(20) $$l = \frac{t_T u}{d} \, .$$

Form the ratio l/L and use (19) and (20) to obtain

$$l = \frac{t_T uD}{T_R Ud} L .$$

From the conditions for miniaturization, u = kU and d = kD so that

$$(21) \qquad l = \frac{t_T}{T_R} L .$$

Thus, the lead for the miniaturized problem, expressed in lengths of target, is directly proportional to the lead for the real world problem where the constant of proportionality is, again, the ratio t_T/T_R.

APPLICATION OF REDUCED SCALE IN AN OPERATIONAL CONTEXT

Hypothetical gunnery problems are used to illustrate the use of the theoretical results of the preceding section. Suppose that the real world weapon of interest is the 7.62mm M14 and the training weapon is the 300 ft/sec muzzle velocity air gun (BB gun). The muzzle velocity of the 7.62mm is V_0=2750 ft/sec and the muzzle velocity of the BB gun is v_0=300 ft/sec. The ratio v_0/V_0 of the two muzzle velocities is 1/9.16. In the form of equation (14),

$$v_0 = \frac{l}{9.16} V_0 .$$

This suggests using a scale reduction factor of k=1/9.

Suppose further that the real world target is an aircraft 45 feet long (D) and traveling on a straight-line course with a velocity of U=102 ft/sec (150 mph). In addition, assume the present range (R) to the target is 900 feet. The outline below gives T_R and V_R for the 7.62mm for R=900 feet.

	7.62mm
Present range, R	900 feet
Projectile velocity at target, V_R	2125 feet per second
Time of flight to target, T_R	0.37 second

By using equation (19), the lead in target lengths is

$$L = \frac{T_R U}{D} = \frac{(0.37)(102)}{45} = 0.84 \text{ target length} .$$

Table 3 lists the velocity, time of flight, and ordinate for the BB gun projectile as a function of present range in increments of 10 feet from 0 to 100 feet.

The lead l in target lengths for the gunnery problem miniaturized by the scale factor k=1/9 can be computed by equation (21)

$$l = \frac{t_T u}{d} = (0.38)\frac{102}{9} \Big/ \frac{45}{9} = 0.86 \text{ target length}.$$

Thus, the two leads are approximately equal, because the times of flight of the two projectiles are almost equal over the two present ranges.

Table 3

Ballistic Data for Air Rifle[a]

(300 Ft/Sec Muzzle Velocity)

	Distance (feet)										
	0	10	20	30	40	50	60	70	80	90	100
Velocity (ft/sec)	300	294	286	280	270	263	255	246	240	233	228
Ordinate (feet)	0	.2	.35	.48	.56	.59	.58	.52	.4	.23	0
Time of Flight (second)	0	.035	.07	.11	.14	.18	.22	.255	.295	.34	.38

[a]These data were provided by the U.S. Army Ballistic Research Laboratories.

Table 4 gives the lead l in target lengths for miniaturized gunnery problems obtained by using a number of scale factors less than 1/9. The real world weapon for all cases is the 7.62mm. In Table 4:

Column 1 shows scale factor k.

Column 2 shows reduced range r generated by the scale factor k and computed by r = 900 k. [Equation (8).]

Column 3 shows time of flight t_r of the BB projectile over reduced range r. [Obtained from Table 3.]

Column 4 shows time of flight of BB projectile over reduced present range divided by time of flight of 7.62mm projectile, T_R, over real world present range R = 900 ft. [T_R is equal to 0.37.]

Column 5 shows lead l in target lengths for miniaturized problem.

[Equation (21) $l = \frac{t_r}{T_R} L$ used to compute l where L = 0.84 target lengths.]

Column 6 shows percentage error E if l is replaced by L.

[Computed by the formula $E = \frac{L - l}{L} 100$.]

Using Table 4, k=1/20, for example, gives a lead l=0.363 target length as compared with the real world lead L=0.863 target length.

A one-ninth scale range is still rather large and a smaller range would be much more desirable in view of space and cost limitations. Column 6 of Table 4 gives the percentage error in lead for each scale reduction factor of the table. It is a rough indication of the size of the lead error made in miniaturizing. Choice of the size of the scale reduction factor k has to balance the space and cost limitations against the magnitude of the lead errors produced by the size of k. Thus, a determination has to be made of the lead errors that can be tolerated without causing negative effects in the training program.

Table 4 illustrates the theoretical results of the preceding section for the 7.62mm and BB guns. It shows that the critical element in obtaining equivalent gunnery problems is the ability to match projectile times of flight; that is, the ability to make t_r match T_R.

Table 4

Lead for Miniaturized Gunnery Problems Using Various Scale Factors

Scale Factor k	Ballistic Characteristics			Lead l (target lengths)	Percentage of Error if l is Replaced by L
	r (ft)	t_r (sec)	$t_r\ T_R$		
(1)	(2)	(3)	(4)	(5)	(6)
1 90	10	.035	.094	.079	90.6
1 45	20	07	.189	.159	81.1
1 30	30	.11	.297	.250	70.3
1 23	40	.14	.378	.318	62.2
1 20	45	.16	.432	.363	56.8
1 18	50	.18	.486	.408	51.4
1 15	60	.22	.567	.476	43.3
1 13	70	.255	.689	.579	31.1
1 11	80	.295	.797	.669	20.0
1 10	90	.34	.918	.771	8.2
1 9	100	.38	1.027	.863	0

DEVELOPMENT OF TRAINING PROGRAM

Approach

A six-hour training program of instruction was developed by the Infantry School Technique of Fire Team and staff members of HumRRO Division No. 5, working jointly and concurrently. The prototype air defense training program, using reduced-scale range facilities, was demonstrated at the Infantry School during the period 5-7 January 1967. A group of 20 riflemen were trained by means of the experimental course and their performance on a service weapon firing test against aerial targets was compared with that of a group which had received no special training.

Prior to the demonstration of the training program at the Infantry School, HumRRO Division No. 5 had conducted limited tests of each phase of the program at Fort Bliss, during the second quarter of FY 1967. These tests provided information concerning (a) the average amount of time required and the accuracy with which trainees could estimate leads of from one to eight aircraft lengths, and (b) the firing accuracy, using the air rifle, of untrained personnel as well as personnel who had received the scaled-down training. These limited tests conducted by HumRRO did not include any live firing of the service weapon; also, the training devices used differed from those employed for the formal demonstration given at Fort Benning.

For the demonstration of the program at Fort Benning, the actual construction and improvement of an existing unused range (Jacelin Range) was accomplished by Technique of Fire Team personnel. Thirty spring-operated air rifles and BB ammunition were obtained by the Infantry School for use in the miniaturized firing portion of the program.

The training program consisted of the following phases, or stations:

Orientation and Fundamentals (1 Hour). To outline the program of instruction, and to teach the trainee the fundamentals of range determination, lead estimation, and methods of engagement.

Aircraft Recognition (1 Hour). To familiarize the trainees with the aircraft characteristics that can be used for recognition, and to explain the methods for using the aircraft recognition flashcards, which were provided as training aids.

Range Estimation (1 Hour, practical exercise). To teach trainees to determine when an aerial target is within effective range for his weapon. This training emphasized the use of the front sight guards of the service weapon or the finger occlusion method as a job aid for range determination.

Lead Estimation (1 Hour, practical exercise). To teach trainees to estimate leading a non-moving target by one, two, and three aircraft lengths.

Lead Tracking and Firing (1 Hour, practice exercise). To familiarize the trainee with the subcaliber training weapon, and to teach him to lead and fire at a miniaturized, moving aircraft silhouette.

Subcaliber Familiarization and Record Firing (1 Hour). To provide coordinated practice in range determination, lead estimation, and practice firing at a 1/10-scale moving target using the subcaliber training weapon.

Phases of the Training

The following sections describe the training methods and devices as used in the Fort Benning demonstration of the program.

Orientation and Fundamentals

The USAIS Project Officer began the orientation period by explaining the necessity of using organic infantry weapons in an air defense role, pointing out that at the present time the foot soldier has had no instruction in the task of engaging a hostile aerial target. The orientation vividly described an infantry soldier who was caught in an open field early on a cold morning. The soldier was fired upon by an enemy aircraft but did not know how to defend himself, other than trying to hide behind some inadequate protection. This orientation was designed to impress upon the trainees the need to develop skill in engaging aircraft with small arms. After providing this motivation, the instructor summarized the training program to be given and the live-firing test that would be conducted subsequently.

A second instructor then explained the fundamentals of the important component skills of range determination, lead estimation, and methods of engaging aerial targets. Two aids to range determination were discussed: the use of the front rifle sight by riflemen and of the index finger by machine gunners. It was pointed out that the maximum effective range for 7.62mm weapons is 350 meters; that when one-half of the apparent aircraft size fills the front sight, the target would be approximately 350 meters away and within firing range; and that when two-thirds of the target is occluded by the index finger, the target is within firing range.

The concept of lead estimation was explained by using the example of a football quarterback throwing a pass to a moving receiver. It was stressed that the gunner must point and fire his weapon somewhere in front of the target in order for the bullet and target to arrive simultaneously at the same point in space, resulting in a hit. Visual aids were used to diagramatically illustrate the concept.

Two engagement methods were described. The Changing Lead Technique was to be used to engage aircraft flying at speeds of up to 200 knots. The instructor explained that the amount of lead needed changes with the engagement situation, but a

good average lead sequence is three apparent aircraft lengths for an incoming or outgoing target and two lengths when the target is near crossover.

When the target speed exceeded 200 knots, the Pattern of Fire Technique was to be used to engage the target. To use this technique, some reference point is selected on the ground by the squad leader, and all weapons are elevated at an angle so that the aircraft flies into the intersecting lines of fire. On the command of "Fire" given by the squad leader, all weapons are fired simultaneously.

Aircraft Recognition

Training Method. The instruction on visual recognition began with approximately 10 minutes of introductory remarks concerning the need for visual recognition of aircraft and the type of aircraft that were included in the training program. The training materials were then distributed to the trainees and instructions were given concerning their use:

Flashcards—Trainees were encouraged to visually pick out cues on the aircraft silhouettes and associate the aircraft name with these cues. Major cues were printed on the reverse side of each card to assist the men in picking out significant distinguishing aircraft features.

Time cards—All study time was to be recorded, indicating whether the men studied as a team or alone. The need for accurate reporting of study time was stressed. The trainees were informed that they would be given a 35mm slide test, covering 17 aircraft, at 1600 hours the next day, and that their test scores would be compared with their study times.

Coach-pupil instruction sheet (Figure 10)—This sheet summarized the coach-pupil learning method which would be used.

The remainder of the orientation period (25 minutes) was spent having the two-man teams practice using the flash cards. The jobs of the coach and the pupil were demonstrated, and the teams practiced with the first aircraft in the series. Next, the class was talked-through the remainder of the coach-pupil method, and the teams then practiced on the next aircraft in the series. With only a few minutes left in the period and only two cards completed, the learning technique was once more restated and questions were answered. The trainees retained the training materials for self-study use.

On the second day all trainees were assembled in a building for about five hours under the supervision of a noncommissioned officer. Part of this time was used for study by the two-man teams.

The classroom proficiency test consisted of 102 slides covering 17 aircraft. Six different aspects of each aircraft were used. During the test each slide was exposed for 15 seconds, followed by a 15-second interval during which the trainee wrote his answer.

Results. The average score was 21.3 correct (21%) with a standard deviation of 14 (a chance score was six slides correctly identified). The test scores ranged from 1 to 56 correct identifications.[1] The correlation between time studied (as reported by trainees) and number of correct responses was 0.27, which is not reliably different from zero.

The average study time was two hours and 40 minutes. Of a total of 51 hours of time studied, ranging from one hour to 5 3/4 hours, an average of approximately 15 minutes per man was spent in solitary study. The majority of study time was used for "buddy" training.

[1] One trainee, who was an avid aircraft fan, obtained 85 correct. His score was not included in the average reported above since this level of enthusiasm and previous knowledge is seldom encountered.

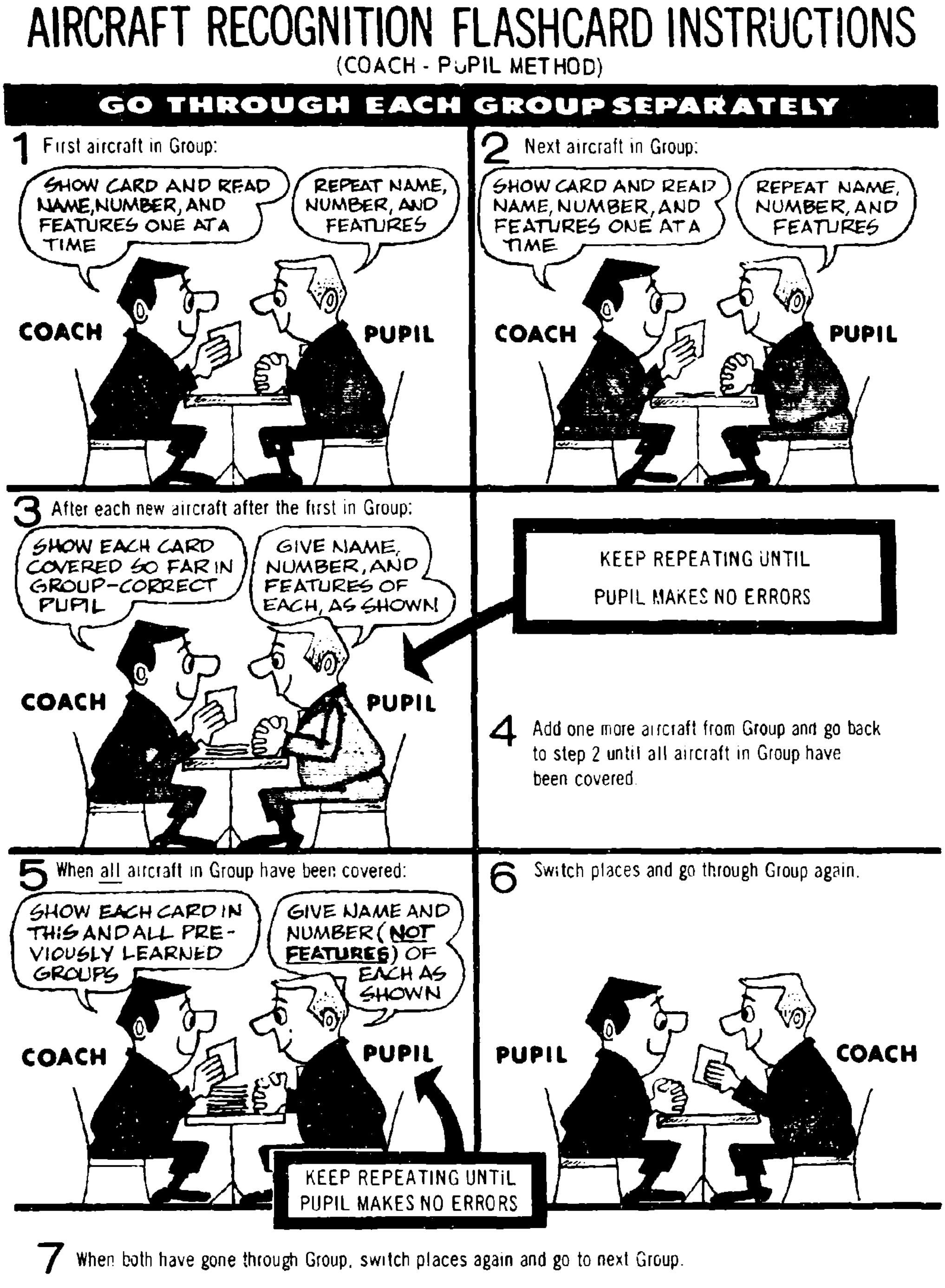

AIRCRAFT RECOGNITION FLASHCARD INSTRUCTIONS
(COACH - PUPIL METHOD)
GO THROUGH EACH GROUP SEPARATELY
1 First aircraft in Group:
SHOW CARD AND READ NAME, NUMBER, AND FEATURES ONE AT A TIME
REPEAT NAME, NUMBER, AND FEATURES
COACH
PUPIL
2 Next aircraft in Group:
SHOW CARD AND READ NAME, NUMBER, AND FEATURES ONE AT A TIME
REPEAT NAME, NUMBER, AND FEATURES
COACH
PUPIL
3 After each new aircraft after the first in Group:
SHOW EACH CARD COVERED SO FAR IN GROUP-CORRECT PUPIL
GIVE NAME, NUMBER, AND FEATURES OF EACH, AS SHOWN
COACH
PUPIL
KEEP REPEATING UNTIL PUPIL MAKES NO ERRORS
4 Add one more aircraft from Group and go back to step 2 until all aircraft in Group have been covered.
5 When all aircraft in Group have been covered:
SHOW EACH CARD IN THIS AND ALL PREVIOUSLY LEARNED GROUPS
GIVE NAME AND NUMBER (NOT FEATURES) OF EACH AS SHOWN
COACH
PUPIL
KEEP REPEATING UNTIL PUPIL MAKES NO ERRORS
6 Switch places and go through Group again.
PUPIL
COACH
7 When both have gone through Group, switch places again and go to next Group.

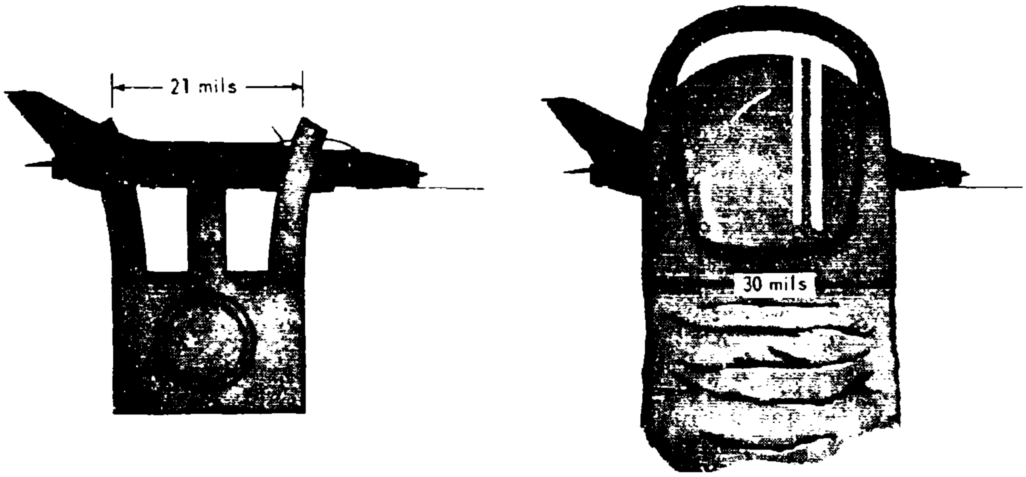
Figure 10

Results from an aircraft recognition training study (6) conducted by HumRRO in 1967 at Fort Bliss were compared with the Fort Benning results. Although the training methods used at Fort Bliss and Fort Benning were not the same, the average achievement levels of the different groups of trainees were quite comparable for equivalent training times. For the nine aircraft that were included in both the Fort Bliss and the Fort Benning training, the average correct identifications were: Fort Bliss trainees, 29%; Fort Benning trainees, 23%.

Range Estimation

Five pairs of trainees were assigned to this station at one time. Riflemen practiced using the front sight of an M14 rifle, and M60 machinegunners practiced using their index finger as an aid in estimating 350 meters (see Figure 11).[2]

Range Estimation Aids



Front Sight Picture of Russian Mig 21
at 350 Meters
(Aircraft Length: 13 Meters)

Index Finger-target Relationship
at 350 Meters
(Index Finger Held at Arm's Length)
(Aircraft Length: 13 Meters)

Figure 11

The training devices consisted of one-foot aircraft silhouettes mounted on poles about 10 feet high. These poles were placed in the ground so that the silhouettes were viewed against a sky background. A length of engineer's tape was tied to the base of the pole; when stretched out, the tape indicated the scaled range of 350 meters. Five different targets were set up in parallel lanes but at varying distances from the starting point of the lanes.

A coach-pupil arrangement was used. The trainees were instructed to begin walking down the lanes toward the aircraft silhouette and to sight down their weapon while moving. At the point along the lane at which the pupil thought he had a sight

[2] M60 machinegunners were included in the experimental program, but not in the live-firing test phase. The offhand firing position used with the air rifles and the low firing rate of the air rifles did not provide a valid method of training machinegunners. Other techniques for reduced-scale training of machinegunners need to be developed.

picture indicating 350 meters—that is, for the rifleman, one-half of the apparent size of the aircraft filled the distance between the front sight guards—he was to stop and so announce to his coach. The coach would then move down to the target, and pick up and stretch out the measuring tape to check the trainee's range estimate. The tape was only long enough to indicate the simulated 350-meter point. If the trainee stopped too soon, he had underestimated the actual distance to the target (that is, more than one-half of the apparent size of the aircraft filled the distance between the front sight guards). Conversely, if the trainee went too far, he overestimated the actual distance (that is, less than one-half of the aircraft silhouette filled the distance between the front sight guards).

As soon as the trainee's estimate had been checked, the trainee moved to the correct range in order to obtain the correct sight picture. The coach then returned the measuring tape to the pole, and both trainee and coach returned to the starting line. The pair of men then rotated to the next lane, and the coach became the pupil for the next trial. The change of coach-pupil and the rotation of lanes after each trial continued until each pupil had learned to determine the correct sight picture for 350 meters with less than a 6% error of estimation (one-half of a step). This, in most cases, required no more than about four or five trials.

Lead Estimation

Ten trainees were assigned to this station at one time to receive instruction and practice using an M14 rifle placed in a pivoting mount. A side-view silhouette of an aircraft was hung from a horizontal wire in front of each weapon position. The wire and attached silhouette could be moved so that the target aircraft would move either one, two, or three target lengths ahead of its original position. All targets were oriented as if they were flying from left to right.

The 10 trainees were assigned to five coach-pupil teams for each trial. The pupil trainee was instructed to position the rifle so that it was pointing ahead of the nose of the aircraft by one, two, or three apparent target lengths. Each trainee used only the target located directly in front of him for lead practice. The set of targets was then moved by an assistant instructor to the appropriate lead, and the accuracy of the pupil's lead estimate was checked by him and his coach. The coach and pupil changed places on alternate trials. Each trainee was given several trials in estimating each of the three leads.

Lead Tracking and Firing

The trainees fired the subcaliber training weapons for the first time at this station. Firing at a stationary target was practiced first to familiarize the trainee with the operation of the air rifle. Each trainee fired 40 to 50 BBs at aircraft silhouettes painted on a sheet metal target board.

The dynamic training device consisted of two adjacent one-foot aircraft silhouettes which slid down a sloping wire (Figure 12). These targets, the leading one painted white and the trailing one painted black, were suspended next to each other from a sloping wire stretched between two poles. The targets were allowed to slide down the wire at a speed that required a one-length lead at the firing distance used (30 feet). If the trainee aimed somehwhere on the moving white aircraft and fired, his BB would hit about the same spot on the black aircraft. Both targets were made of metal so that a hit would provide auditory feedback, but it could not be determined which target had actually been hit.

Each trainee fired several magazines of 40 to 45 rounds. Five firers were on the line at once, so it was not possible to give individual trainees feedback concerning aiming errors or hits.

Lead Tracking and Firing Device

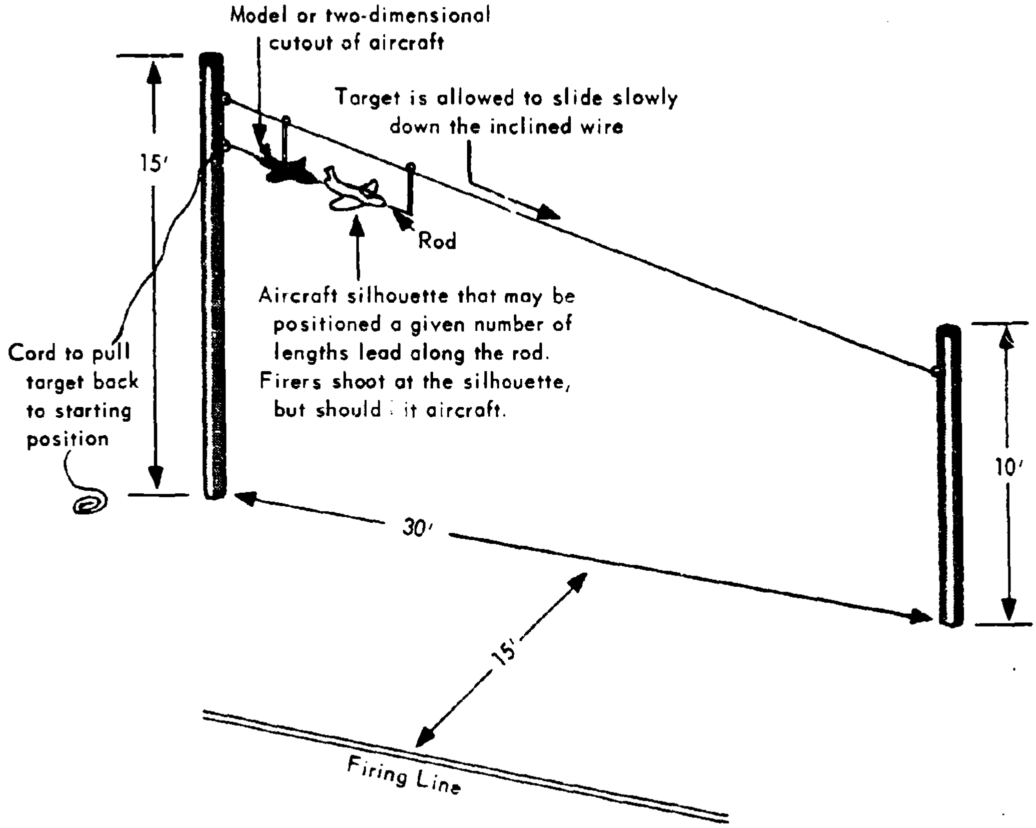


Figure 12

Subcaliber Familiarization and Record Firing

Method. The trainees were divided into two firing orders. The firing line was located 20 meters from the target course. Two 1/4-ton vehicles were used to transport the 1/10-scale silhouette targets. The two-dimensional aircraft silhouettes (4-foot black silhouettes of jet aircraft printed on white paper) were stapled to both sides of a mounting panel attached to a wooden superstructure fitted on top of the vehicle (see Figure 13). The distance from the ground to the silhouette was approximately 15 feet. One target-carrying vehicle would make a pass from right to left, and, as soon as the pass was completed, the second target vehicle would begin a pass from left to right.

All men in one order fired on each pass, with each man firing between two and four rounds. Each man began firing with a full magazine of 48 rounds. The target vehicles continued to pass in front of the firing line until all men had expended all the rounds. Periodically, the men checked whether they were out of ammunition by firing into the ground. It is estimated that each man fired 40 to 45 rounds at the target from a full magazine.

As soon as all men in one order had fired their rounds, the target vehicles were waved off the course and the number of hits on the aircraft silhouettes were

Moving Target-Holding Device Mounted on Jeep (Artist's Concept)

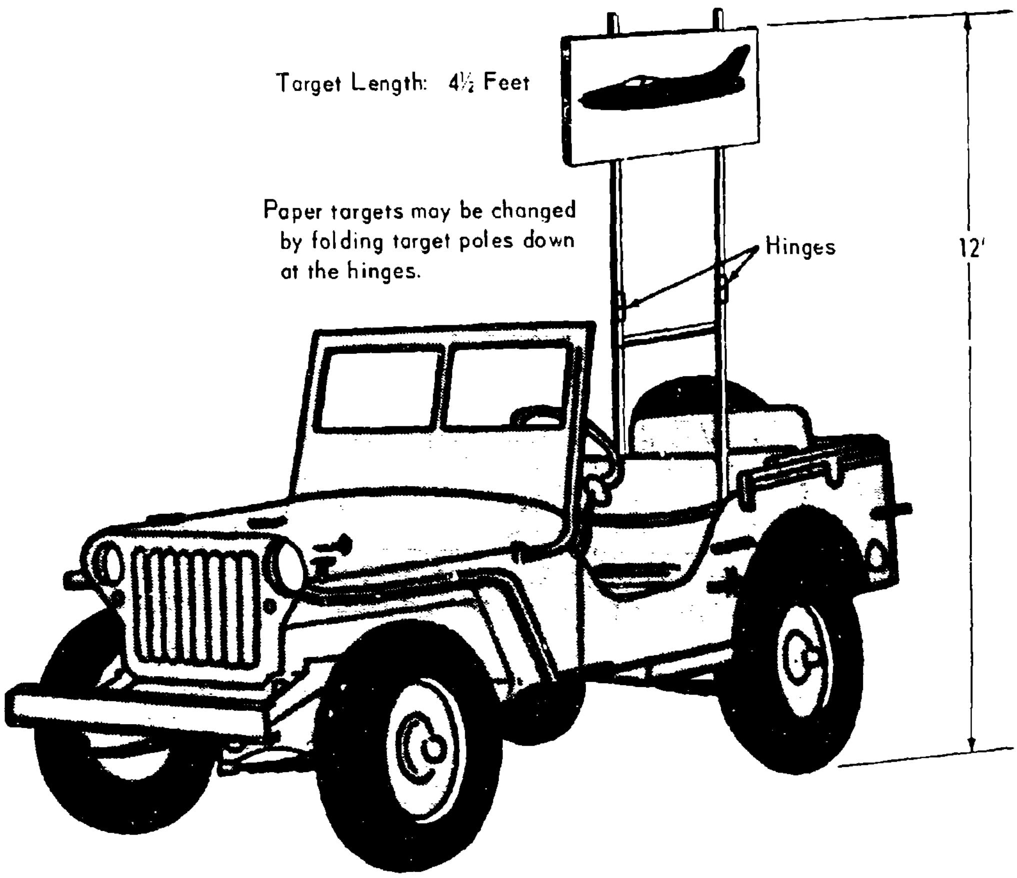


Figure 13

counted and recorded. A new target was mounted, and the second firing order moved to the line to practice firing. Periodically the trainees were reminded to lead the target the correct number of target lengths and to track the silhouette smoothly while firing.

Each order fired two full magazines during practice firing and 25 rounds for record fire. A hit count was made after each firing order had expended all rounds in the magazine.

Subcaliber Firing Results. Each firing order consisted of 13 men who fired the training weapon. The results of the familiarization and record firing of the training weapon are shown in Table 5.

When each order practice-fired the second magazine, the targets were not well stapled to the panel board. The target was loose in a few places, and it appeared that some BBs had rebounded from the panel, making a second hole in the target. Since it was not possible to determine the frequency of rebounds, the scores for the second practice firing probably were spuriously high. This would account for some of the apparent decrease in accuracy from the second practice firing to the record firing.

Table 5

Familiarization Firing Data

Firing Phase	Hits	Rounds Fired	Percentage of Hits
Practice Firing			
First Magazine Fired			
First Order	17	480	
Second Order	31	520	
Total	48	1000	4.8
Second Magazine Fired			
First Order	93	550	
Second Order	81	520	
Total	174	1070	16.2
Record Firing			
First Order	23	325	
Second Order	15	300	
Total	38	625	6.1

Service Weapon Firing Test

Test Design. In order to determine the validity of the miniaturized training, two groups of 20 riflemen were used. Group I went through the training program, while Group II received only a 10-minute orientation period in which the need to lead the moving target in order to hit it was pointed out. During the service rifle test, the men fired in groups of 10. Each man was instructed to attempt to fire the complete magazine of 20 rounds during each pass of the target. Five passes were flown for each group of 10 riflemen.

Each man was to fire 100 rounds of ball ammunition with the M14 rifle. The target was towed at crossing ranges that varied from approximately 75 to 200 meters and at altitudes from less than 100 to about 300 feet. The towing speed was almost constant, varying slightly around 155 knots. The target was towed both left to right and right to left. The target was dropped by the tow aircraft after five passes had been flown for each firing group.

Range Facilities. Jacelin Range at Fort Benning, Georgia, was used for the live firing test. The firing fan at the range was approximately 80°. The aerial target sleeves provided by the Navy were 20 feet long, and the diameter varied from 26 inches at the front to 48 inches at the rear of the target, providing a presented target area of 40 square feet. The target was towed 5000 feet behind the aircraft, thus assuring that the aircraft was well out of the firing fan when the gunners opened fire.

The tow aircraft was a Navy US-2C aircraft, which was in constant communication with a Forward Air Control (FAC) team from the Air Force. The FAC team was located in the range control tow along with the Range Control Officer.

Personnel

Group I—The 20 riflemen in the training group, who were provided by the Infantry School, had a rank of SP4 or less, averaged 21 years in age, and had been in the

Army an average of one and one-half years. According to the most recent M14 qualification scores, the group had four men classified as Experts, seven as Sharpshooters, and nine as Marksmen.

Group II—The men who did not go through the training program were members of the Weapons Department, Technique of Fire Team. The range of ranks was from SP4 to SFC. The average age was 29, and average time in service was 10 years. The group had six Experts, 10 Sharpshooters, and four Marksmen.

An incidental difference between the two groups was noticed. Group II was generally of a stouter build and seemed to track the target more smoothly during the live firing test; that is, they were less affected by weapon recoil.

RESULTS OF SERVICE WEAPON FIRING TEST

The trained group fired a total of 1964 rounds, hitting the target 13 times. The first order had five hits for 974 rounds fired; the second order had eight hits for 988 rounds fired.

The untrained group fired 2000 rounds and obtained four hits.

A statistical analysis (the chi-square test) comparing the number of hits indicated that the difference between the hits for the two groups was statistically reliable at the .05 level of significance.[3]

In order to make the hit data obtained in the live firing test tactically meaningful, they were extrapolated to indicate the approximate number of hits that could be obtained on a tactical target, such as observation aircraft similar to the O-1A. The target area of the O-1A that would be available for a crossing course is approximately 138 square feet. The area of the aerial sleeve target used during the live firing test was 40 square feet. A scaling factor was determined by dividing the area of the sleeve into the O-1A's area, resulting in a factor of 3.45.

Using this factor to extrapolate hit data to tactical targets, Group I would have 45 hits for 1964 rounds (hits=2.3%), and Group II would have 14 hits for 2000 rounds fired (hits=0.7%).

COMPARISON OF FULL-SCALE AND MINIATURIZED TRAINING FIRING DATA

The live firing test following the full-scale training given in February 1966 resulted in 10 hits out of the 960 rounds fired. The sleeve used had a target area of 36 square feet, which, when compared to the O-1A target area, resulted in a scale factor of 3.84. The scaled-up data resulted in 38 hits, which was approximately 4% as compared to the 2.3% hits obtained in January 1967 after the miniaturized training.

A statistical comparison of the scaled-up data from the 1966 and 1967 tests resulted in a chi-square value of 6.54. Since this was statistically significant beyond the .02 level, it was concluded that a reliably greater percentage of hits was obtained in the February 1966 firing test.

[3] The use of a chi-square analysis is technically not totally valid for evaluating hit results obtained by groups of individuals, as a chi-square analysis assumes experimental independence of the event data. There is a possibility that the event data (hits) were not independent since one firer may have obtained more than one hit on the sleeve. By assuming independence of the hit events, the use of the chi-square test produces a conservative evaluation of statistical reliability.

CONCLUSIONS

The reduced-scale training program demonstrated in 1967 was effective in developing some skill in engaging aerial targets. The effectiveness of the demonstrated program, however, was not as great as that achieved by the 1966 program, which used full-scale training without live firing practice.

It seems probable that the 1967 miniaturized training program had the following deficiencies:

(1) The prototype training program did not provide any means for giving feedback to the trainee concerning the correctness of his lead estimation for a moving target. The training method and devices should be modified to permit provision of information to individual trainees concerning the correctness of their leads.

(2) The prototype training emphasized engagement of lateral targets, that is, targets flying at a tangent to the gunner's position. Both the range estimation training, the lead practice, and the subcaliber firing should include incoming and oblique target-aspect angles.

(3) The Familiarization and Record Firing Phases employed a two-dimensional target silhouette mounted on a background board. Since there probably was a tendency for trainees to lead the front edge of the *board* rather than the silhouette, the background board should be eliminated, and the two-dimensional target should be replaced with a three-dimensional 1/10-scale mock-up of an aircraft. (A suggested configuration for a suitable three-dimensional target is described in Appendix A.)

(4) The subcaliber training weapon, because it required manual cocking, was unsatisfactory for training men to smoothly track and repeatedly fire at a moving target.

The weapon procedures used in the 1967 program for engaging aerial targets with the service rifle appeared to be inadequate in two major respects:

(1) The firing technique required aiming *over* the rear aperture sight. This practice automatically produced excessive superelevation, which at 150-200 meters slant range probably resulted in firing above the sleeve target.

(2) The rate of fire employed with the service rifle appeared too rapid for many of the men in the trained group. In their attempt to achieve semi-automatic fire of 10 rounds per pass of the target sleeve, many of the men in the "trained" group were noticeably physically perturbed by the recoil and appeared to have difficulty in simultaneously maintaining an even rate of fire and tracking. In contrast, the more experienced and heavily-built noncommissioned officers of the untrained group appeared to track the target more smoothly and to fire at a more regular rate, and did not appear to be shaken by the successive recoils. This observation suggests that either (a) a rate of one round per second is too high for engaging aerial targets, or (b) the firing rate obtained with the manually cocked training weapon was so slow that the subcaliber training subsequently interfered with establishing the appropriate tracking and firing actions needed for service rifles.

Chapter 4

IMPROVEMENTS TO THE MINIATURIZED TRAINING

SUGGESTED IMPROVEMENTS

Range Estimation Training Device

The miniaturized version of the training program for range estimation used two-dimensional metal silhouettes, one foot in length, mounted on a metal pole pressed into the ground. It is suggested that the two-dimensional silhouettes be replaced with three-dimensional models of aircraft. Some commercially produced plastic aircraft models are manufactured on a 1/40 scale, a size that would be appropriate for range estimation.

Using a three-dimensional target, practice on range estimation could be given for head-on and oblique aspect angles, in addition to the lateral aspect included in the experimental training content. A single miniature target, mounted on a pole, could be used for simultaneous training of several men, as shown in Figure 14.

Training in Lead Estimation

Lead estimation appears to be the most difficult skill required of a small arms gunner when he attempts to engage aerial targets. When an operator of a visually sighted weapon engages an aircraft on a crossing course, he must fire at an imaginary aim point ahead of the aircraft. Learning to accurately estimate the lead, and to continuously track and fire at the imaginary aim point requires considerable practice. The miniaturized program demonstrated in 1967 did not include any means for providing individual feedback to each trainee concerning the magnitude or type of aiming error he committed when practicing leading and firing at the 1/10-scale targets. It was evident during the demonstration training that a trainee who does not regularly receive accurate information about the nature of his errors will not be able to improve his performance level efficiently.

A scaled-down version of the lead-tracking training device that was used in the 1966 full-scale training program could be employed for the reduced-scale training. The construction details and specifications for a suitable training device are presented in Appendix B.

The 1/40-scale static lead training device and the 1/40-scale sliding silhouette training device used in the miniaturized program could be replaced by a single training step using the 1/10-scale, vehicular-mounted target and the lead tracking device shown in Appendix B.

Upon completion of the range determination :ing, the trainees could move to the lead tracking and subcaliber firing range and practice estimating one, two, and three leads, using the apparent length of a stationary target as the visual reference for lead distance. Pairs of trainees would rotate between the "coach" and "pupil" positions at each training device. By successively positioning the target vehicle at several points along the course, the incoming, crossing, and outgoing station lead situations could be simulated.

Three-Dimensional Training Device for Range Estimation

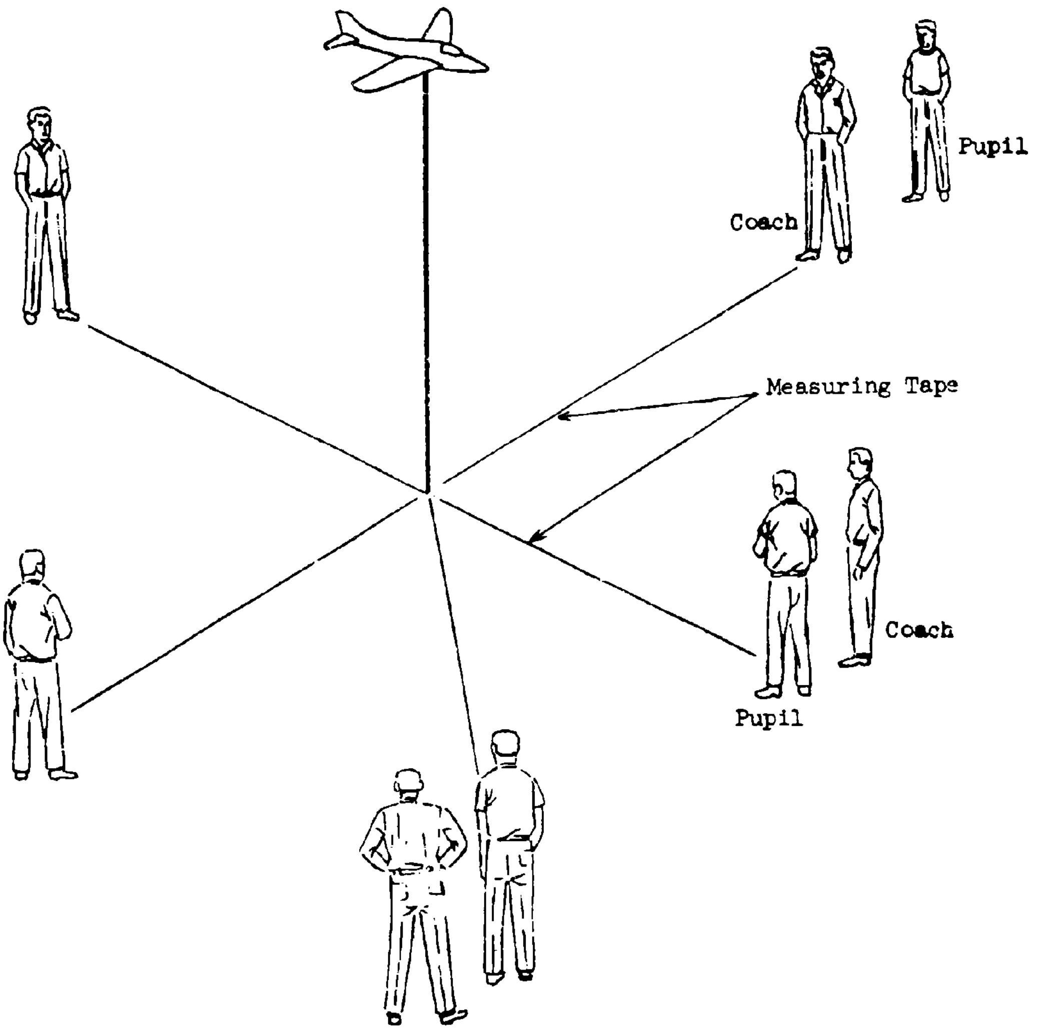


Figure 14

The static lead training would be followed by dynamic tracking practice with the lead tracking device. By using the coach-and-pupil method, pupil-trainees would have considerable practice in which the coach-trainees would provide continuous feedback concerning the accuracy of the estimated leads and the type of errors committed (leading or lagging).

It is estimated that each pair of trainees would need about two hours to acquire the necessary static and dynamic lead training. The total number of men that could be trained in this two-hour period would be determined by the number of tracking devices and the number of target-carrying vehicles available.

SUBCALIBER FAMILIARIZATION AND RECORD FIRING

The amount of subcaliber familiarization training and the record firing test in the reduced-scale demonstration seemed satisfactory. However, the 1/10-scale target used should be three-dimensional, and the target aspect angles should be increased to include simulated passes that are nearly head-on. The construction details and specifications for a locally fabricated 1/10-scale airplane are presented in Appendix A.

Use of a three-dimensional target, in comparison with a two-dimensional target, has the following advantages:

(1) Firing at near head-on and tail aspect angles can be practiced with the training weapon by moving the firing positions as close to the wheeled vehicle track as pedestrian-vehicle safety considerations permit—for example, five feet from the edge of the road. By elevating the three-dimensional scale target to heights greater than 15 feet, the more difficult task of tracking and firing at large elevation angles also could be practiced.

(2) A three-dimensional metallic target would provide auditory feedback when hit. In addition, if the target were repainted from a spray can after several passes, or after each record firing, recording of obtained hits for each squad of trainees may be possible. No extraneous and incorrect reference points would be present on the three-dimensional target to interfere with estimating the correct lead.

SUBCALIBER TRAINING WEAPON CHARACTERISTICS

In contrast with the locally fabricated training devices used in the reduced-scale training, a suitable subcaliber training weapon is not currently available to support this type of training.

Desired Muzzle Velocity. In designing the reduced-scale training, the speed of the wheeled vehicle which transports the reduced-scale target was kept well within safe speed limits for unpaved roads or trails. A scaled-down target size that could easily be accommodated by the wheeled vehicle was desired. Finally, it was considered paramount to find a scale factor that could easily be achieved in a subcaliber training weapon. As a result of analysis of these concurrent requirements, a reduced-scale factor of one-tenth was selected for the training devices. With this scale factor, the muzzle velocity of the training weapon should be fairly close to 300 feet per second in order to simulate the approximate time of flight of the 7.62 and 5.56mm bullets.

Other scale factors could be used; for example, let us assume that an otherwise suitable and inexpensive training weapon was available, but it had a muzzle velocity of 450 ft./sec. If this training weapon were used, a scale factor of 1/6.7 would have to be used for determining the length of the reduced-scale target and, *more importantly*, the required speed of the target-moving vehicle. In order to scale a 200-knot aircraft to a scale of 1/6.7, the ground vehicle would have to maintain a speed of approximately 35mph, the maximum speed allowed (as far as the Provost Marshal is concerned) for wheeled vehicles operating on unpaved surfaces on a military reservation. If aircraft speeds higher than 200 knots were to be simulated, special authority from the Provost Marshal would be required. If trainees were positioned close to the line of vehicular movement for firing practice on near head-on aspects, safety considerations might also limit the maximum speed permitted for the wheeled vehicle.

In consequence of such potential problems, it was concluded that the training weapon should have a muzzle velocity of 300 ft./sec. (plus or minus 25 ft./sec.).

Loading and Firing Cycle. The reduced-scale training is designed to teach aircraft engagement using semi-automatic and automatic weapons. The operation of automatic-loading service weapons requires the shooter to repeatedly regain the correct sight picture

while continuously maintaining the correct lead. Ideally, the subcaliber shoulder-fired training weapon would be designed to simulate, in a realistic manner, the shoulder recoil pressure and the muzzle-lift that occurs with the service rifle, since these are forces that destroy the sight picture. Such a subcaliber device undoubtedly would cost more per unit than the service rifle itself. This degree of simulation probably could not be justified.

However, a subcaliber device that has an automatic loading feature and at least semi-automatic firing capability is needed. A hand-cocked, spring-operated BB gun is not an ideal training device since the cocking operation greatly interferes with continuous tracking and aiming. It was concluded that a semi-automatic air rifle having a "ready magazine" capacity of 10 shots should be procured for this reduced-scale training.

Physical Appearance of the Training Weapon. There is a prevalent opinion that a training device or weapon must look, smell, weigh, feel, taste, and act like "the real McCoy" in order to be an effective training aid. Duplication of the size and weight of the service rifle would be important if the recoil characteristics of the subcaliber training weapon duplicated those of the service rifle, since recoil does influence the accuracy of aiming and the rate of accurate fire that can be directed at a target. The reduced-scale training seeks to develop skill in engaging aerial targets with continuously well-aimed fire. Conceivably, a "featherweight" training weapon could be developed that would economically simulate the recoil and muzzle-lift characteristics of the service rifle. Since it would load and operate on different principles, there would be no requirement that it "look like" a service rifle, particularly since most trainees would probably have the training weapon in their hands no more than eight hours during their total commitment to military service.

It was concluded that the physical appearance and/or weight of the training weapon should not be a limiting, restricting, or desired characteristic of the training weapon ("desired" characteristics tend to result in increased costs for training devices).

Sights. The effectiveness of using the service rifle for engaging aerial targets will be dependent upon the correctness of the sight picture used. Therefore, it is suggested that (a) the sights on the subcaliber training weapon be accurate facsimiles of their service rifle counterparts, and (b) the sight radius duplicate that of the service rifle. The rear sight should be adjustable in both windage and elevation to permit "zeroing" the training weapon.

The sighting technique used in the reduced-scale demonstration required the riflemen to aim over the top of the rear aperture, resulting in excessive superelevation of the weapon. A suggested alternative procedure requires use of a rear sighting point which is between the rear aperture ring and right or left rear sight-guard flange. For left-to-right courses, sighting between the aperture ring and the right guard automatically would provide a lead in the correct direction. Similarly, sighting between the aperture ring and the left guard would be appropriate for a right-to-left crossing target. For incoming and outgoing targets, the soldier would sight through the rear aperture.

ARMY UTILIZATION OF THE RESEARCH

In May 1968, the Department of the Army published Training Circular (TC) 23-15, *Engagement of Aerial Targets with Small Arms.* This TC, which was prepared by the U.S. Army Infantry School, describes the miniaturized training program demonstrated in 1967, as modified by a majority of the suggestions for improvement described in this chapter.

In the Training Circular, the static lead estimation station using suspended silhouettes and the sliding wire lead practice stations were replaced by a station which uses the lead estimation training device (the Aerial Target Lead Estimation Training Device) and a 1/10-scale silhouette mounted above a 1/4-ton vehicle.

Since the 1/10-scale silhouette was retained, rather than using a 1/10-scale three-dimensional target, the Familiarization and Record Firing phases are limited to tangential courses. No practice firing can be given using targets moving obliquely toward the infantryman.

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AND
APPENDICES

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Appendix A

Specifications for a Three-Dimensional 1/10-Scale Target

The target aircraft, shown in Figure A-1, is made of sheet metal (20-gauge or heavier) assembled from parts shown in Figure A-2. All parts are joined with lap joints and secured by soldering or use of blind rivets.

The completed model is mounted on a one-inch board, 6" by 16", which fits into the opening in the bottom between the wings. A 3/4" pipe flange is mounted in the center of the mounting board to provide a means to support the target above the transporting device. The pipe must be guyed to prevent excessive swaying when the vehicle is in motion.

Three-Dimensional 1/10-Scale Target

Figure A-1

Plans for Three-Dimensional 1/10-Scale Target

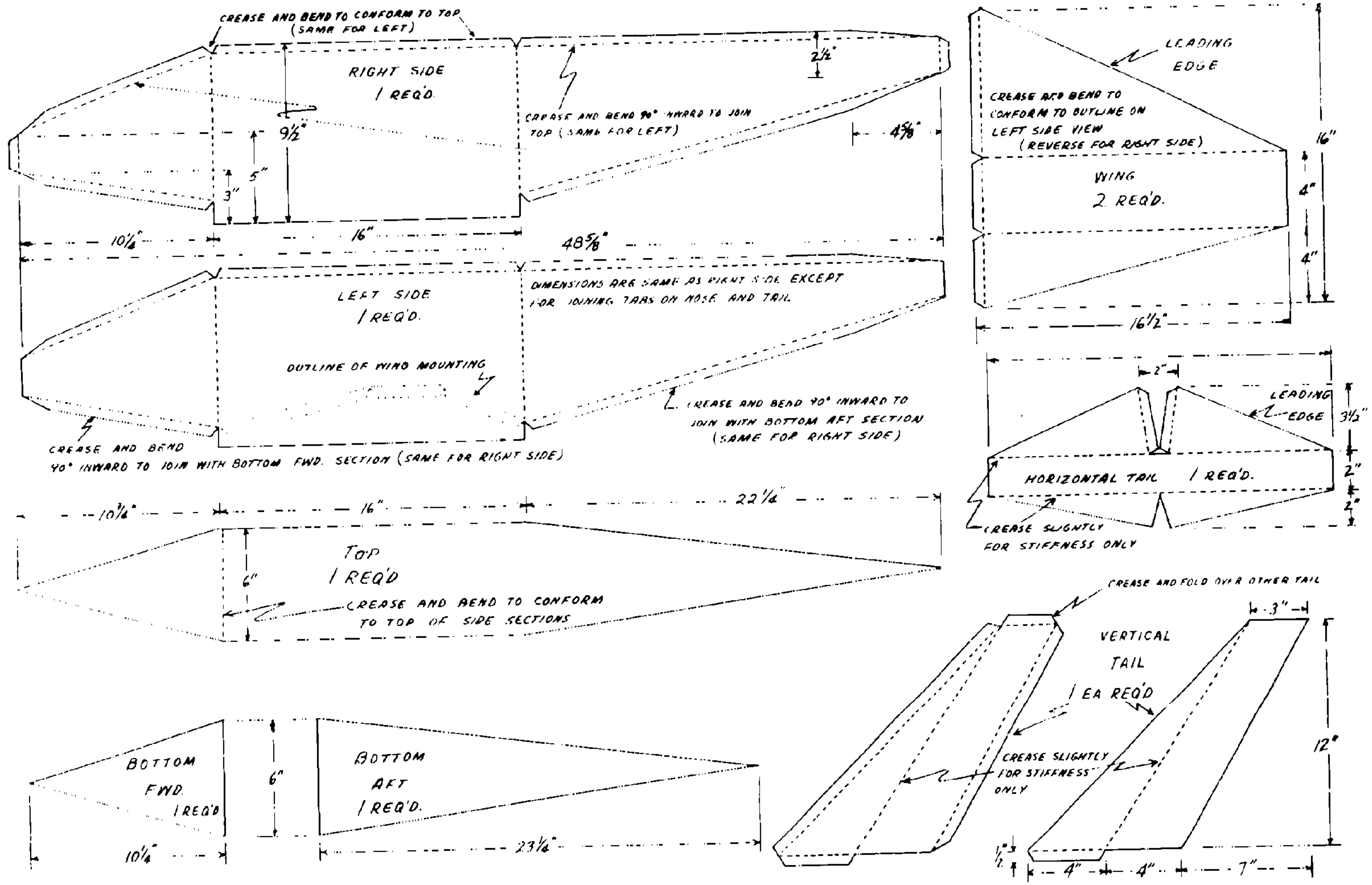

Figure A-2

Appendix B

Specifications of SKYFIRE Tracking Boards for use With Miniaturized Range Training

The tracking board diagramed in Figure B-1 is similar to the boards used in tests at Fort Benning in February 1966. A turnbuckle has been added to allow for the adjustment of the 6° angular displacement of sighting arm A with respect to arm B. Disk B has the 1/4" hole offset one-half inch from its center instead of 1/4" as previously used. No sights are shown mounted on the sighting arm, but these may be of any type.

The board has been designed to give leads appropriate for a target whose speed is 150 knots, altitude 150 feet, and crossing range 200 meters.

The tracking board has a line-of-sight error of 24 inches due to the spacing between the sighting arms. For a full-size target, the two-foot error has little effect. When a miniature range is used, however, the two-foot difference becomes important: If the firer is properly leading a four-foot-long target for hits on the nose, the coach's pointer will be aimed at a point two feet behind the nose. The coach would consider the firer to be correctly leading for a hit anywhere on the plane if the coach's pointer was aimed in a zone extending from the middle of the four-foot target to two feet behind the tail of the target.

Tracking Board Diagram

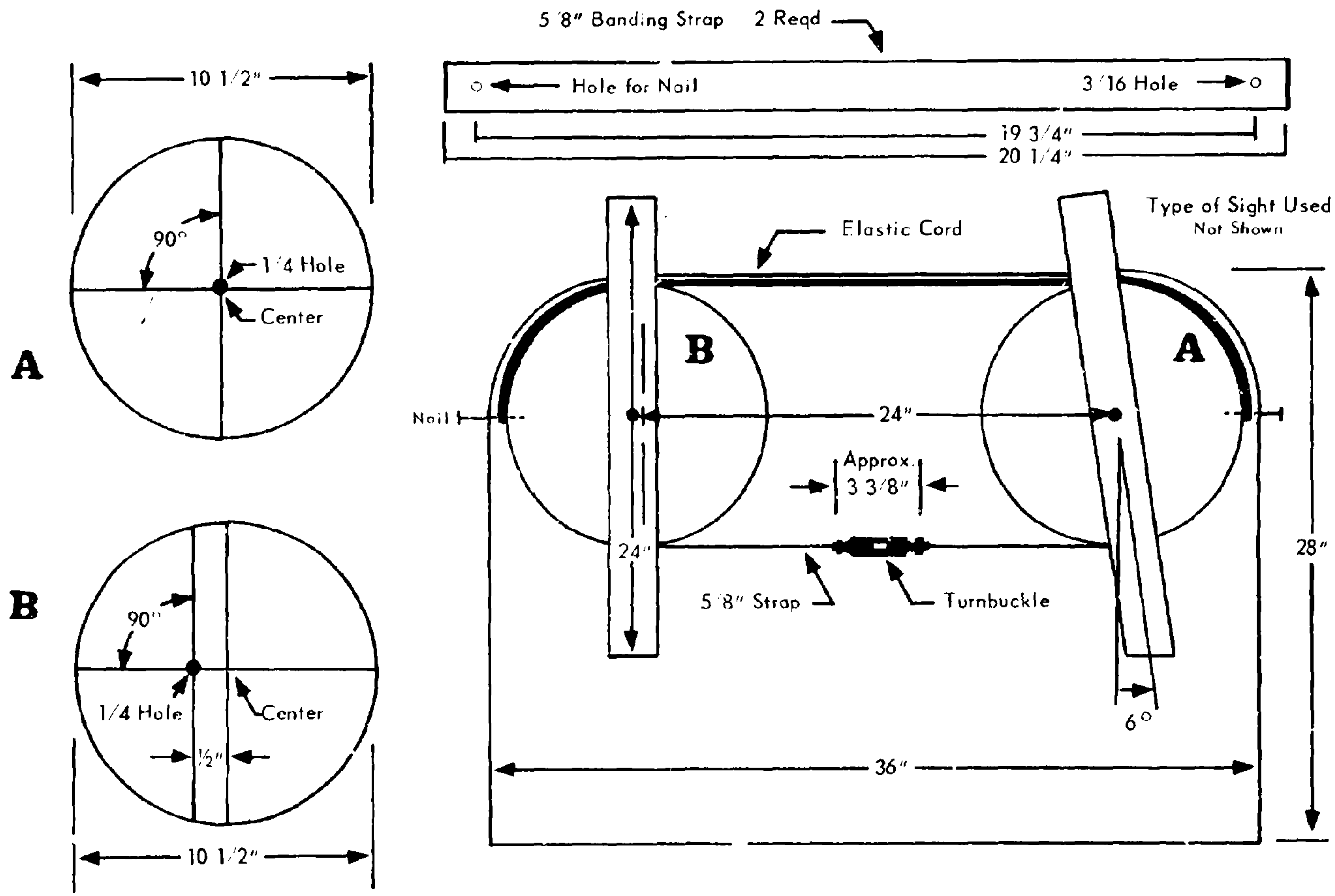

Figure B-1

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13. ABSTRACT

Studies were performed to develop low-cost techniques for training infantrymen to engage low-flying aircraft with small arms. The first approach included training on estimating distance, leading, and tracking, using a special training device. After training, in live firing using a sleeve target towed at low altitudes, 16 riflemen obtained 10 hits for 960 rounds fired. Adjusting for the small size of the sleeve, it was estimated that 4% of the rounds would have hit a full-size aircraft. In the second approach, a miniaturized program used air rifles against 1/10-scale aircraft silhouettes. This training was also evaluated by a live-firing test. The 20 men who received the training achieved 13 hits for 1964 rounds fired; another group of 20 untrained riflemen obtained 4 hits for 2000 rounds. Adjusting for reduced target size, it was estimated that the hit percentages would be 2.3% and 0.7%, respectively. It was concluded that while both approaches to training were effective, the miniaturized program could be improved by incorporating the leading/tracking training device used in the initial method.

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